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# A SYNOPTIC TEXT-BOOK

OF

# ZOÖLOGY

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# A SYNOPTIC TEXT-BOOK

OF

# ZOÖLOGY

*FOR COLLEGES AND SCHOOLS*

BY

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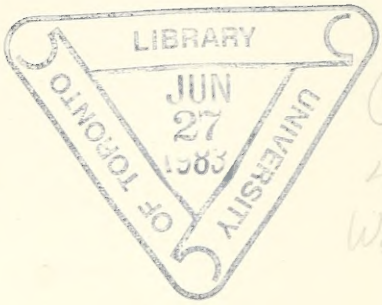


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# PREFACE

The students in our American colleges who take up the elementary study of zoölogy fall for the most part into two classes: on the one hand those who purpose to become specialists in some one of the zoölogical branches, and on the other those who pursue the subject merely as a part of a liberal education, or as an adjunct to the more complete study of other sciences in which some knowledge of the phenomena of animal life is desirable. As a rule, the method of instruction employed for these two groups of students is, from practical necessity, nearly the same, although the second group is much the larger. Our college students have had very diverse preparations for this subject. All presumably have at least some slight knowledge of elementary chemistry and physics, and all probably know a few biological facts, but their knowledge of plants and animals is apt to be fragmentary and not very systematically arranged, and they have but little conception of the fundamental principles of biology, of the relationships of various types of organisms to one another, or of the broader problems of ecology and theoretical biology. These students are, however, of some maturity, they are beginning to form rudimentary conceptions, at least, of the significance of life and of the simpler philosophical problems.

The up-to-date text-books at present available in English seem to be designed either exclusively for pupils of our high schools and academies, or else for college students who intend to become specialists in zoölogy, so that the college professor must refer his students to books either too elementary for them, or too unreliable because antiquated, or to such as enter into details which belong more properly to the specialist or to the subject of comparative anatomy studied with extensive dissecting in the laboratory.

In the following pages I have endeavored to incorporate such facts as are adapted to American college students or high school students in their final years. The first two chapters are devoted to a brief consideration of the more important general principles underlying the biological sciences. While there is much difference of opinion among teachers as to the best method of presenting the subject of zoölogy to the adult student, all are agreed that some knowledge of these principles should be the first step; whether this knowledge should be imparted as a preliminary part of the general subject of zoölogy, as in this book, or as a separate subject, — biology, — more or less complete in itself, is comparatively immaterial perhaps; these chapters have been written for those who prefer the former method, — recognizing that the student of zoölogy wishes to get at the actual study of animal life as soon as possible, — with as brief an introduction as is necessary to make the facts of the science intelligible; they can readily be omitted or rapidly reviewed, without affecting the usefulness of the book, by those who prefer to begin the subject with a special text-book of biology. This portion of the book, instead of giving a long list of definitions of various biological sciences and a discussion of cytological problems, briefly defines zoölogy, treats of the phenomena of living matter in general, shows the relation of protoplasm to the cell, the cell to the tissue, the tissue to the organ, and the organ to the individual, and then gives the fundamental principles of zoölogical classification.

The second portion of the book is devoted to a description of the various animal types. Here the chief object has been to present such facts concerning the structure and life history of the different groups as will enable the elementary student to gain a conception of those characteristics which are fundamentally distinctive and yet, for the most part, easily recognized. Thus, except in the lowest groups, it is the differences of external structure which have been given the prominent place, although in no case has the general internal anatomy been ignored. The classification has in most instances been carried as far as the orders; occasionally suborders are mentioned. While there are scarcely two zoölogists who agree on the sub-

ject of animal classification, it will be found that the system adopted here is in accord with the general conception of the relationships of animals held by scientists to-day. To the beginner the classification of animals appears a well-nigh hopeless, interminable task, and for this reason it has seemed best to retain such types as the Vermes and the Arthropoda, designating their chief subdivisions as subtypes, while explaining that the latter are more of the nature of types; in this way a certain unity, artificial, it is true, is maintained amongst the very diverse representatives of the invertebrates, and this, I believe, is of notable assistance to the elementary student without leaving him with an erroneous conception of their general relationships.

While this portion of the subject is apt to be treated in a way that is dry and unattractive to the beginner, my purpose has been to introduce, whenever practicable, interesting facts concerning such phenomena as commensalism, symbiosis, and parasitism, the transmission of malaria and yellow fever by mosquitoes, the cause of trichinosis and filariasis, and such interesting habits as the division of labor in colonies and the storing of food for the young. These are matters which the general student especially wishes to know, and of which many who undertake to specialize are often ignorant.

The third portion of the book deals with the general principles of zoölogy. As is well known, many German text-books discuss these principles before they take up the special groups of animals about which the generalizations are made — a method which seems to many like putting the cart before the horse. When the student is, to some extent, familiar with the different kinds of animals, he is ready to consider such subjects. Here is taken up first the distribution of animals, palæontologically and geographically, then an outline of the various theories of evolution is given, followed by a review of our knowledge of the behavior of animals, considered, to some extent, psychologically; with, finally, a brief history of the science of zoölogy. The definitions of the different branches of the biological sciences have been placed in an appendix.

The laboratory method is now the accepted method of instruc-

tion in all biological branches, and this book is designed to be used for constant reference, not only in connection with lectures and recitations, but also in the laboratory and in museum and field work. All of these methods of instruction should be employed in an elementary college course in zoology. No special directions for laboratory work have been given, for teachers of this subject have all had such laboratory training that they are familiar with the methods best suited to the particular conditions under which they are teaching, while there are, further, many excellent laboratory guides already in print. I have for many years combined field work, particularly at the seashore, and visits to museums with the other methods of instruction, and believe that they are of great assistance to the beginner and should be pursued more extensively than they are at present in many colleges.

No apology is necessary for the large number of illustrations; in a book of this type, which aims to give the student a general survey over the entire field of animal life, illustrations are as necessary as charts are to a lecture. In the laboratory the student can, under the most favorable conditions, see only a relatively few representative animals; in the museum the smaller animals are not the most striking and are soon forgotten, while enlarged models of microscopic animals are rare; the text-book, then, must supply these deficiencies, hence the large number of figures illustrating the external form of animals, supplemented by some diagrams to illustrate types of internal structure and occasionally embryological stages.

It has been the purpose of this book to include in a single volume of convenient size all that is necessary for an elementary course in zoology in our American colleges, suitable for the general student and at the same time a proper introduction for extended treatises, such as the text-book of Parker and Haswell, or the books distinctively on comparative anatomy, for the student who wishes to pursue the subject further. There is at present no book on zoology that exactly meets this need or that treats the subject in a way suited to the adult student who is, to some extent, capable of thinking for himself and forming his own judgments. Hence the treatment here is new;

the selection of facts and their arrangement differ from that of existing text-books; in fact, this is not a text-book as that term is properly used to-day when applied to extended treatises, usually in more than one volume, which enter into the subject exhaustively. Here the whole subject is epitomized; the fundamental facts of the science, not the theories of the author, are presented to the student; each subject is handled synoptically, not treated fragmentarily, as in the majority of the elementary books, which are for the most part adapted to children only; thus, the purpose has been to present a *résumé*, readable it is hoped, which shall be suited to the large class of students for whom such a treatment is needed. Hence the title of the work.

I wish here to express my thanks to Miss E. Wood, palæontologist, formerly of the Massachusetts Institute of Technology, and now connected with the Department of Geology at Washington, who was kind enough to read the chapter on prehistoric animals in manuscript. I am also deeply indebted to my former teacher, Dr. E. L. Mark, Professor of Zoölogy at Harvard, who has read the preface and table of contents, and given me several helpful suggestions on the general arrangement of the book. And my thanks are especially due to Professor W. T. Sedgwick, of the Massachusetts Institute of Technology, who has looked over the entire manuscript and made valuable suggestions. His continued encouragement and kindly interest during the preparation of the book have done much to lighten the drudgery of compilation, so onerous in the elementary treatment of so broad a subject as zoölogy has become to-day.

A. W. WEYSSE.

BOSTON, MASSACHUSETTS,
August, 1903.

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In descriptions of illustrations, male animals are frequently represented by the astronomical sign for Mars, ♂, and female by the sign for Venus, ♀.

# OUTLINE OF THE CLASSIFICATION OF ANIMALS

## KINGDOM ANIMALIA

### SUBKINGDOM I. PROTOZOA

**TYPE I. PROTOZOA.**
- *Class I. Rhizopoda.*
  - Order 1. Foraminifera.
  - Order 2. Heliozoa.
  - Order 3. Radiolaria.
- *Class II. Sporozoa.*
  - Order 1. Gregarinida.
  - Order 2. Coccidiida.
  - Order 3. Myxosporida.
  - Order 4. Sarcosporida.
  - Order 5. Hæmosporida.
- *Class III. Mastigophora.*
  - Order 1. Flagellata.
  - Order 2. Choanoflagellata.
  - Order 3. Dinoflagellata.
  - Order 4. Cystoflagellata.
- *Class IV. Ciliata.*
  - Order 1. Holotricha.
  - Order 2. Heterotricha.
  - Order 3. Peritricha.
  - Order 4. Hypotricha.
  - Order 5. Suctoria.

### SUBKINGDOM II. METAZOA

**TYPE II. CŒLENTERATA.**
- **Subtype I. Porifera.**
  - *Class. Porifera.*
    - Order 1. Myxospongiæ.
    - Order 2. Calcispongiæ.
    - Order 3. Ceratospongiæ.
    - Order 4. Silicispongiæ.
- **Subtype II. Cnidaria.**
  - *Class I. Hydrozoa.*
    - Order 1. Hydridæ.
    - Order 2. Hydromedusæ.
    - Order 3. Siphonophora.
  - *Class II. Scyphozoa.*
    - Subclass I. Anthozoa.
      - Order 1. Octocorallia.
      - Order 2. Hexacorallia.
    - Subclass II. Scyphomedusæ.
  - *Class III. Ctenophora.*

**TYPE III. ECHINODERMATA.**
- *Class I. Crinoidea.*
- *Class II. Asteroidea.*
- *Class III. Ophiuroidea.*
- *Class IV. Echinoidea.*
- *Class V. Holothuroidea.*

**TYPE IV. VERMES.**
- **Subtype I. Platyhelminthes.**
  - *Class I. Turbellaria.*
  - *Class II. Trematoda.*
  - *Class III. Cestoda.*
- **Subtype II. Nemertina.**
- **Subtype III. Nemathelminthes.**
  - *Class I. Nematoda.*
  - *Class II. Acanthocephala.*
- **Subtype IV. Chætognatha.**
- **Subtype V. Rotifera.**
- **Subtype VI. Molluscoidea.**
  - *Class I. Bryozoa or Polyzoa.*
  - *Class II. Phoronidea.*
  - *Class III. Brachiopoda.*

**Subtype VII. Annelida.**
*Class I. Chætopoda.*
Subclass I. Polychæta.
Subclass II. Oligochæta.
*Class II. Gephyrea.*
*Class III. Hirudinea.*

**TYPE V. ARTHROPODA.**
**Subtype I. Crustacea.**
*Class I. Entomostraca.*
Order 1. Phyllopoda.
Order 2. Ostracoda.
Order 3. Copepoda.
Order 4. Cirripedia.
*Class II. Malacostraca.*
Subclass I. Leptostraca.
Subclass II. Arthrostraca.
Order 1. Isopoda.
Order 2. Amphipoda.
Subclass III. Thoracostraca.
Order 1. Cumacea.
Order 2. Stomatopoda.
Order 3. Schizopoda.
Order 4. Decapoda.
Supplementary order. Xiphosura.
**Subtype II. Arachnida.**
Order 1. Scorpionida.
Order 2. Pseudoscorpionida.
Order 3. Pedipalpi.
Order 4. Solpugida.
Order 5. Phalangida.
Order 6. Araneida.
Order 7. Acarina.
Supplementary order 1. Linguatulida.
Supplementary order 2. Pycnogonida.
Supplementary order 3. Tardigrada.
**Subtype III. Tracheata.**
*Class I. Protracheata.*
*Class II. Myriapoda.*
Order 1. Chilopoda.
Order 2. Diplopoda.
*Class III. Hexapoda* or *Insecta.*[1]
Order 1. Thysanura.
Order 2. Pseudoneuroptera.
Order 3. Orthoptera.
Order 4. Hemiptera.
Order 5. Neuroptera.
Order 6. Lepidoptera.
Order 7. Diptera.
Order 8. Coleoptera.
Order 9. Hymenoptera.

**TYPE VI. MOLLUSCA.**
*Class I. Amphineura.*
Order 1. Solenogastres.
Order 2. Placophora.
*Class II. Gastropoda.*
Order 1. Prosobranchia.
Order 2. Opisthobranchia.
Order 3. Pulmonata.
*Class III. Scaphopoda.*
*Class IV. Lamellibranchia* or *Pelecypoda.*
*Class V. Cephalopoda.*
Subclass I. Tetrabranchiata.
Subclass II. Dibranchiata.
Order 1. Decapoda.
Order 2. Octopoda.

**TYPE VII. CHORDATA.**
**Subtype I. Enteropneusta.**
**Subtype II. Tunicata.**
**Subtype III. Cephalochorda.**
**Subtype IV. Vertebrata.**
*Class I. Cyclostomata.*
*Class II. Pisces.*
Subclass I. Elasmobranchii.
Order 1. Selachii.
Order 2. Holocephali.
Subclass II. Teleostomi.
Order 1. Ganoidei.
Order 2. Teleostei.
Subclass III. Dipnoi.
*Class III. Amphibia.*
Subclass I. Urodela.
Subclass II. Anura.
Subclass III. Gymnophiona.

[1] For extended classification of the Insecta see page 226.

*Class IV. Reptilia.*
- Order 1. Squamata.
  - Suborder 1. Lacertilia.
  - Suborder 2. Ophidia.
- Order 2. Rhynchocephalia.
- Order 3. Chelonia.
- Order 4. Crocodilia

*Class V. Aves.*
- Subclass I. Dromæognathæ.
  - Order 1. Struthiones.
  - Order 2. Apteryges.
  - Order 3. Crypturi.
- Subclass II. Impennes.
- Subclass III. Euornithes.
  - Order 1. Desmognathæ.
    - Suborder 1. Steganopodes.
    - Suborder 2. Herodii.
    - Suborder 3. Anseres or Chenomorphæ.
    - Suborder 4. Accipitres.
    - Suborder 5. Psittaci.
    - Suborder 6. Striges.
    - Suborder 7. Picariæ.
  - Order 2. Schizognathæ.
    - Suborder 1. Pygopodes.
    - Suborder 2. Turbinares.
    - Suborder 3. Gallinæ.
    - Suborder 4. Grallæ.
    - Suborder 5. Gaviæ.
    - Suborder 6. Limicolæ.
    - Suborder 7. Pterocletes.
    - Suborder 8. Columbæ.
  - Order 3. Ægitognathæ or Passeres.

*Class VI. Mammalia.*
- Subclass I. Ornithodelphia or Monotremata.
- Subclass II. Didelphia or Marsupialia.
- Subclass III. Monodelphia or Placentalia.
  - Order 1. Edentata.
  - Order 2. Sirenia.
  - Order 3. Cetacea.
  - Order 4. Ungulata.
    - Suborder 1. Perissodactyla.
    - Suborder 2. Artiodactyla.
    - Suborder 3. Proboscidea.
    - Suborder 4. Hyracoidea.
  - Order 5. Rodentia.
    - Suborder 1. Sciuromorpha.
    - Suborder 2. Myomorpha.
    - Suborder 3. Hystricomorpha.
    - Suborder 4. Lagomorpha.
  - Order 6. Insectivora.
  - Order 7. Chiroptera.
  - Order 8. Carnivora.
    - Suborder 1. Fissipedia.
    - Suborder 2. Pinnipedia.
  - Order 9. Primates.
    - Suborder 1. Lemuroidea.
    - Suborder 2. Anthropoidea.

# Part I

## INTRODUCTION

# CHAPTER I

## THE WORLD OF LIFE

Every one recognizes that plants and animals are living things; the study of plants constitutes the science of botany, while the science of zoölogy (Gr. ζῶον, animal, and λόγος, discourse) concerns itself with the study of animals; the term *biology*, the science of life, may be used to include them both. So far as our present knowledge goes, no living matter can come into existence from lifeless matter; every plant has been derived from some other plant, and every animal has developed from some other animal; the spontaneous generation of life from the lifeless was a theory long believed, but for which there is no foundation of fact in science to-day. Whether in the history of the world living matter may ever have arisen from lifeless matter we are not prepared to say; it is, however, very probable that such was the case, but we have no evidence in fact that any life at present on the earth has come into existence except from preëxisting life. On the other hand, living matter appears to be subject to the same chemical and physical laws as lifeless matter, but the former exhibits certain phenomena which we call life, which are absent from the latter; life is probably due to some peculiar arrangement of the most minute constituent parts of certain combinations of chemical elements, so that forms of energy are brought into play which produce the phenomena of life and are absent or inert in lifeless matter. This theory is substantiated by the fact that, in the analysis of living matter, the weight of the substances obtained is the same as the weight of the living body, although for the purpose of analysis the organism must be killed. Life, then, is not a material substance, it has no weight, it is a condition of matter.

The peculiar properties of living matter are (1) its ability to

produce certain chemical compounds never formed by lifeless matter, (2) its method of growth, and (3) its power of reproduction.

In its chemical composition it invariably contains some form of proteid; the proteids are complex combinations of carbon, oxygen, hydrogen, nitrogen, and sulphur. They vary considerably in their relative composition, but since they occur as a constant constituent of living matter and are formed only by living matter, they afford a chemical characteristic for all kinds of organisms.

Growth, or an increase in size, is a characteristic of all organisms, whether plant or animal, and of some inorganic forms of matter as well, such as crystals and stalactites. But the growth of these lifeless bodies is brought about merely by accretion, the addition of particles to the outer surface. Growth in living bodies, on the other hand, is due to a process of intussusception, an interposition of particles amongst those which already exist; it is thus a growth within the mass.

In the third place, living matter is capable of giving off portions of its own substance which may grow into complete individuals; in other words, it has the power of reproducing itself, a phenomenon never exhibited in lifeless matter.

When we come to study the finer structure of living bodies we find that they consist of a translucent, semifluid substance, practically colorless and very finely granular. This substance is called protoplasm and is sometimes spoken of as the physical basis of life. In its active state it contains a large amount of water, but its exact structure and composition are still in dispute. It is a very complex combination of carbon, oxygen, hydrogen, nitrogen, and sulphur, and often contains phosphorus as well; the sulphur and the phosphorus are in very small quantities. We usually find, more or less intimately associated with its proteid constituents, certain carbohydrates, compounds of carbon, hydrogen, and oxygen, of which the most familiar examples are starch ($C_6H_{10}O_5$) and the various sugars; fats, which contain relatively much less oxygen than the carbohydrates, are also commonly found in protoplasm. It has not been possible to obtain a definite chemical symbol for protoplasm; whether its elements are combined in fairly definite

proportions capable of infinite variations or whether in varying proportions we are unable to say, but the bit of protoplasm floating in a pond which develops into a frog must be very different from the bit beside it which develops into a fish, even though under the highest powers of the microscope and in the laboratory of the chemist we may be unable to distinguish between them.

The simplest forms of life consist of microscopic bits of protoplasm, within which we can in most cases distinguish a more highly refractive spot, often spherical, which is called the nucleus. This is merely differentiated protoplasm, which because of its special structure and functions is sometimes called nucleoplasm, while the surrounding protoplasm is called cytoplasm. Such a nucleated mass of protoplasm is termed a cell, and is frequently surrounded by a more or less firm membrane, called the cell membrane or wall, a product of the cytoplasm; but this membrane is not considered an essential part of the cell as usually defined, since it is often absent.

Among the simplest animals and plants each individual consists of a single cell, which is capable of performing all the functions necessary for its own existence and for reproducing itself; but most organisms are much more complicated in structure, for they consist, not of a single cell, but of many cells, some of which perform one function and some another, so that there is a division of labor amongst them. These special groups of cells are called tissues, and necessarily undergo considerable modification of structure to fit them for their special use, so that we may briefly define a tissue as a group or complex of similarly differentiated cells, which have a common function to perform. When we consider the functions of a plant or animal, however, we see that they are not performed by one tissue exclusively, but that several tissues are brought into play, even for a very simple form of activity; thus the tissues of the body are more or less united into organs, such as the root of a plant or the foot of an animal, each of which performs some one or more of the functions necessary for the existence of the individual or the race. It is for this reason that we speak of plants and animals as organisms, — composed of organs, which in turn are composed of tissues, and these of

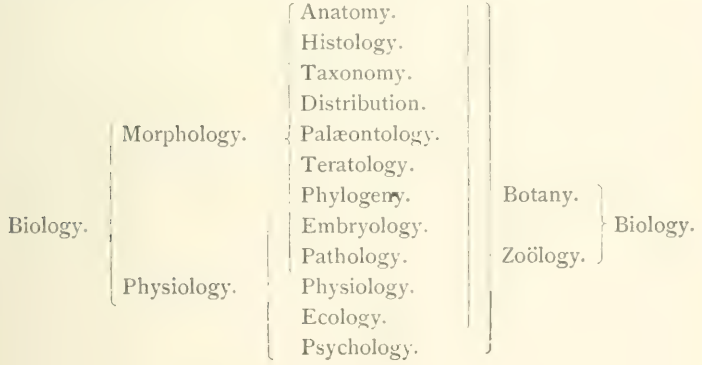
cells. And although the unicellular plants and animals can have no tissues or organs in this sense, yet since they perform functions analogous to those of the higher forms of living matter, we are correct in considering them organisms also.

Thus we see that living matter exists in the form of individuals which are merely so many isolated particles; the largest of these particles in existence to-day are represented among plants by the giant redwood trees of California, among animals by some of the whales, and yet these largest masses of living matter are microscopic as compared with many masses of inorganic matter, such as mountains, lakes, and oceans; living matter never attains to such colossal proportions. And if we consider further the total number of organisms inhabiting the earth to-day, we shall soon see that by far the vast majority are in truth microscopic; a single drop of fluid may contain more living bacteria than there are human beings in a large city, and yet each bacterium is a complete and distinct individual.

Most organisms then are entirely invisible to the naked eye; the animals and plants which we can see form a very small proportion of the individuals in existence; presenting, as they do, such a vast variety of form and structure, it is clearly quite impossible for a single human being to become familiar with them all. The number of animals in existence is inconceivably great, but happily the number of different kinds of animals falls within our human conception. Estimates concerning this number must necessarily vary, they cannot be exact; it has been said that there are in the neighborhood of two million different kinds of living animals, certainly a large number. But we find that these different animals can all be assigned to two or three large groups, the members of which all resemble one another in certain respects and differ in others from all the members of the other groups. These can further be subdivided into smaller groups and the process continued until we have numbers which can be handled with some facility. Thus by a system of classification we bring to light for the first time the fundamental resemblances between various animals and in consequence their relationships; hence we see that classification is an absolute essential to a knowledge of the science of zoölogy, it brings order

out of chaos, and the way in which this is accomplished we shall consider in the following chapter.

It will be evident at once that a classification laying any claims to accuracy must be based on as minute a knowledge as possible of individual animals, their structure, their behavior, not only to one another, but to the entire organic and inorganic world, their development, their past history on this earth, and their present distribution on it. Each of these subjects thus becomes a matter for research, a science in itself, but all really branches of the greater science of zoölogy. Nearly all of the various medical sciences are in fact branches of zoology and botany. For the sake of convenient reference the following diagram has been placed here to show the general relation of some of the more important specialized sciences to zoölogy and botany, while the student is referred to the appendix for a description of their particular fields of investigation.



# CHAPTER II

## THE GENERAL PRINCIPLES OF ZOÖLOGICAL CLASSIFICATION

In classifying plants and animals, as in the classification of any objects, we group together those which resemble one another in one or more respects; but we must be careful to select as a basis for our grouping characteristics which have a real, fundamental, and not merely a superficial, significance. Thus two animals, a shark and a whale, for example, may both inhabit the water, but their structure, method of development, and food may differ widely; the habitat, then, would be, not a natural but an artificial basis for classification. All biological classification is based upon structure and development and at times on function as well; in many cases the structure of the adult plant or animal is sufficient to show its relationship to other plants and animals; in some instances it is necessary to consider the development also, and at times the latter forms the only criterion. Thus our present system of classification rests upon anatomy and embryology, the sciences of structure and development; but even then there must necessarily be some difference of opinion among scientists as to the amount of importance to be attached to the various morphological details, *i.e.* the details of form in its broadest sense; furthermore, our knowledge of the structure and development of organisms is constantly increasing, new facts are being discovered, and hence it is not surprising that our systems of classification are undergoing continual changes, and that there is much diversity of opinion among specialists on this subject. For the present there can be, therefore, no fixed, final classification of plants and animals; but our knowledge of the biological sciences, the sciences of life, is now sufficiently broad so that further changes are not likely to affect the larger

groups to any notable extent, but will have to do chiefly with the smaller subdivisions.

All organisms are classified in one of two groups called kingdoms, the plant kingdom and the animal kingdom or *Kingdom Animalia*. These are naturally the largest groups, including as they do all the plants on the one hand, and all the animals on the other. These kingdoms are composed of several smaller groups known as types; there are a number of terms used synonymously with type by different scientists, such as phylum and branch. Types are divided into classes; classes into orders; orders into families; families into genera; genera into species; and sometimes species into varieties. Each of these groups, from the kingdom to the family inclusive, may be divided into subgroups, so that we may have subkingdoms, subtypes, etc., and it is sometimes necessary to make further subdivisions, which are known by various names. For the elementary student in zoölogy it is sufficient to carry the classification as far as the order or at most the suborder. The names of the principal divisions may be arranged as follows: —

Kingdom.
Type.
Class.
Order.
Family.
Genus.
Species.

Up to the year 1735 there was the greatest confusion in the naming of animals. Common names were used, and naturally in different localities the same animal was known by different names, and different animals might be known by the same name. But in the year mentioned a Swedish scientist, named Linnæus, published the first edition of a book called "Systema Naturæ," in which he divided all animals into classes, orders, genera, and species, and adopted Greek and Latin names for these various groups so that their use might be universal and not confined to any one country. He devised further the binomial nomenclature, by means of which each animal has two names, consisting of the generic name followed by the specific

name, the first being written with a capital letter, the second with a small letter unless it is derived from a proper name, when it may be written with a capital, although the tendency among scientists to-day is to begin all specific names with small letters. Thus the dog is known scientifically as *Canis familiaris*, the wolf as *Canis lupus*, the fox as *Canis vulpes*, — they are different species of the same genus, Canis; in the same way the common cat is *Felis domestica*, the lion *Felis leo*, and the tiger *Felis tigris*.

So there are in general as many kinds of animals as there are species, and each has a name which can be used and understood by all scientists, whatever their nationality. In reality there are more kinds of animals than there are species, for, as we noted above, species may be divided into varieties; there are many kinds of domestic dogs and cats, and many other species of animals are likewise varied; hence we may have several varieties of the same species; thus the lion of Barbary is called *Felis leo barbarus*; somewhat different is the lion of Persia, called *Felis leo persicus*; while the lion of Senegal is again sufficiently different to be considered a distinct variety, *Felis leo senegalensis*.

The system of nomenclature suggested by Linnæus has been taken as the foundation of all biological classification, the classification of living things. It sometimes happens that an animal discovered and named by one scientist is later discovered and named differently by another who is ignorant of the earlier author's work. In all cases, however, the name accepted as permanent is that which was first published; after the name of the species there is frequently written the initial or abbreviated name of the writer who first distinguished it; thus, the name of the dog may be written *Canis familiaris* Linn., indicating that Linnæus was the author of this name.

It is a matter of common observation that no two men are exactly alike; so no two other animals are exactly alike, and this is not surprising, since every individual is the result of the fusion of two unlike germ cells arising from two different individuals. But this individual variation does not exceed certain limits; the question arises, When are differences sufficiently great to place plants or animals in distinct varieties of the

same species, and when so great that we must place them in distinct species? To answer the second question first,—the generally accepted rule is that if two organisms will interbreed and produce fertile offspring they belong to the same species. There are a number of animals which will interbreed and produce sterile offspring, especially under domestication; such offspring are known as hybrids. The mule, the result of crossing the mare with the he-ass, is a familiar example; the dog will cross with the wolf, jackal, and fox; the sheep, with the goat and the pig; hares with rabbits, various species of birds with one another, and similar instances occur in the lower animals and in plants as well. In a few cases hybrids have been known to reproduce, so that while the rule holds in general it is not absolute. These facts are of great importance, as we shall see in a later chapter when we come to consider the origin of species together with other problems in theoretical biology.

Considering, then, animals which freely interbreed and produce fertile offspring as belonging to the same species, we note in many cases certain characteristics constantly present in some individuals and absent in others; these characteristics are capable of being transmitted to the offspring, and thus we have varieties; familiar examples are the setter and the terrier among dogs, the fantail and the tumbler among pigeons. The offspring which result from the crossing of varieties are known as mongrels, and they are always fertile, with a few exceptions among plants. Members of the same species are always fertile except after prolonged interbreeding, when the offspring of a single pair are continually chosen for reproduction; in such cases absolute sterility has been obtained in some plants, and the same law doubtless holds for animal species.

In a complete study of plants and animals we have to consider, not only organisms which live at present on the earth, but others which have lived in the past and may or may not have become extinct. For this study a pretty complete knowledge of existing plants and animals is desirable and also some acquaintance with geology as well; but in taking up the classification of animals it is frequently convenient to refer to representatives of various groups which have existed in the past history of the earth, and so we may note here one or two facts which properly belong

to the chapter on palæontology, the science of prehistoric organisms. The solid crust of the earth consists, geologically speaking, of rocks, whether in the form in which we commonly conceive of rocks, or in the form of gravel, sand, clay, or mud. These rocks are, broadly speaking, of two kinds: the igneous rocks, which are formed for the most part below the surface of the ground and owe their structure to the action of heat, they contain no remains of organisms; and the sedimentary or stratified rocks, which have been formed for the most part under water by the deposition of their constituents in layers or strata. In these strata are found the remains of plants and animals; these remains are known as fossils.

A fossil, literally anything dug up, consists of the remains of any organism which has been covered up by natural processes. As is well known, the soft parts of organisms usually disintegrate when the organism dies, so that, as a rule, only the hard parts remain; thus we have the most abundant fossils from animals which had hard parts, such as coral-skeletons, shells, and bones. These hard parts may be preserved in their original condition by the simple hardening into stone of the substance in which they are imbedded; or the original skeleton may be dissolved away and replaced by a mineral deposit, frequently by silica, the process being so gradual as to reproduce in great detail the structure of the original, as we see in petrified trees; in still other cases fossils consist merely of impressions made by organisms or parts of organisms in soft mud or clay, which has afterward become hardened, as in the fossil footprints of birds and reptiles.

The fossiliferous rocks were originally laid down in approximately horizontal, parallel strata, the oldest of course being the deepest or farthest from the surface of the earth; but in the course of the earth's history these strata have become folded, twisted, and broken in various ways, so that we find outcroppings at the surface of the earth of strata of very different ages. The classification of the various strata is pretty extensive, as they are very numerous; for our purpose it is sufficient to note the names and order of succession of the main divisions, so that the student may have an approximate idea of the relative position in the series of any particular system of strata. There are four great

groups or eras: the Archæan or oldest, the Palæozoic, the Mesozoic, and the Cenozoic or most recent. These are divided into various systems or periods, which may be tabulated as follows, the most recent being at the top of the table, the oldest at the bottom: —

| | | |
|---|---|---|
| Cenozoic | Recent | Quaternary or Post Tertiary |
| | Pleistocene | |
| | Pliocene | Tertiary |
| | Miocene | |
| | Eocene | |
| Mesozoic | Cretaceous | |
| | Jurassic | |
| | Triassic | |
| Palæozoic | Permian | |
| | Carboniferous | |
| | Devonian | |
| | Silurian | |
| | Cambrian | |
| Archæan | Laurentian | |

One of the most significant phenomena met with in any attempt to classify animals lies in the fact that we find at times groups whose affinities are doubtful. We may have, for example, two groups of animals differing strikingly in certain morphological characteristics; a third group may combine these differences and thus form a sort of connecting link between them, while at the same time it is difficult to say which of the two it resembles the more. So it is a matter of no little interest that in attempting to separate plants from animals we should find groups which show affinities to both kingdoms.

The most important of these groups consists of the slime-moulds; they are fully described in most text-books of botany under the name Myxomycetes, but since some zoölogists classify them with the unicellular animals as Mycetozoa (Gr. μύκης, a fungus, and ζῶον, animal), we may note briefly their structure and life-history here. They are found on decaying organic matter, such as leaves and bark, where they exist as irregularly shaped masses of protoplasm, containing many nuclei and en-

dowed with amœboid movements, creeping movements characteristic of the genus Amœba, to be described in the next chapter; this structure is called a plasmodium, and its color varies in different species, being often whitish or yellowish. They feed largely on bacteria, which are minute unicellular plants occurring in great abundance in decaying organic matter.

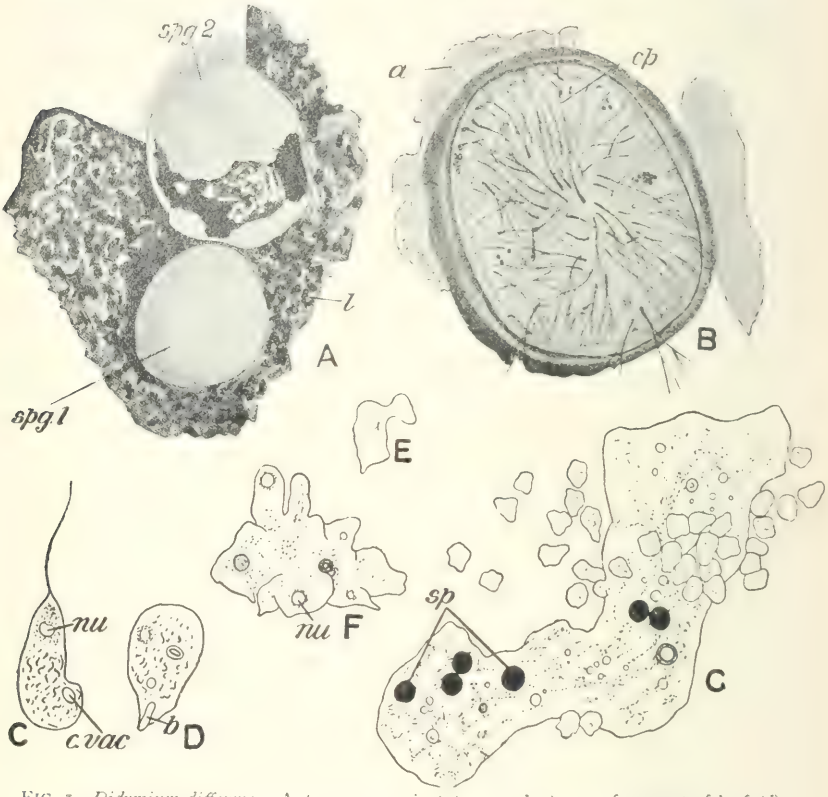



FIG. 1. *Didymium difforme*. A, two sporangia (*spg.* 1 and 2) on a fragment of leaf (*l*); B, section of sporangium, with ruptured outer layer (*a*), and threads of capillitium (*cp*); C, a flagellula with contractile vacuole (*c. vac*) and nucleus (*nu*); D, the same after loss of flagellum; *b*, an ingested bacillus; E, an amœbula; F, conjugation of amœbulæ to form a small plasmodium; G, a larger plasmodium accompanied by numerous amœbulæ; *sp*, ingested spores. (After Lister, from Parker and Haswell's Text-book.)

After a time portions of the protoplasm of the plasmodium assume more definite shapes and secrete firm membranes about themselves, thus forming closed capsules or cysts, which may be spherical, ovoid, or considerably elongated, and in some cases

are raised on stalks. The protoplasm within the cyst then divides into a large number of minute nucleated particles, each with a firm wall of cellulose about it; these particles are called spores, and hence the cyst is called a sporangium. After a time the sporangium is ruptured, and finally the protoplasm emerges from the spore and moves about like a unicellular animal with amœboid movements, and feeds on bacteria. These motile particles may be called amœbulæ. In time many of them coalesce to form a plasmodium with a common mass of protoplasm, but with distinct nuclei, and thus the life-cycle is completed. (Fig. 1.) Their amœboid movements and method of feeding incline us to place them among the animals; on the other hand the minute structure of the sporangium and the method in which the spores are formed within it are strikingly like what we find in some of the lower plants called fungi; hence it is difficult to say in which kingdom these organisms are more properly placed.

# Part II

## SYSTEMATIC ZOÖLOGY

# CHAPTER III

## SUBKINGDOM I. PROTOZOA

### TYPE I. PROTOZOA

The Protozoa (Gr. πρῶτος, first, and ξῶον, animal) are the simplest organisms which clearly belong to the animal kingdom. They live either in fresh or salt water, or in damp places, or, in the case of those which are parasitic, within the bodies of higher animals. The characteristic which distinguishes them from all other groups of animals is the fact that each protozoon consists of a single cell. In most cases each individual leads a free life, independent of its neighbors, but not a few live associated together in groups or colonies. The cells composing these colonies, however, represent each a complete individual, — as a rule physiologically complete, though in a few exceptional cases there is a slight difference of function among the individuals in a colony. Thus the protozoan colonies differ from the multicellular animals, for in the latter there is always a division of labor corresponding to a structural differentiation of cells.

They are for the most part extremely small, so that a microscope is necessary to determine their structure, though some are large enough to be seen with the naked eye, and some of those which have been preserved as fossils are decidedly macroscopic. Yet, despite the fact that the Protozoa are minute and unicellular, and, as we say, the simplest animals, they exhibit a considerable differentiation of structure, as one might well infer, since here a single cell has to perform all the functions of the animal body, such as motion, alimentation, respiration, excretion, and reproduction, which in the higher animals are severally performed by different groups of cells, conforming to the principle of a division of labor. Such a division of labor is on the whole

impracticable in a unicellular organism, though even here certain parts of the cell are differentiated or set apart for the performance of definite functions. Thus we find in almost all the Protozoa a nucleus or nuclei, and even in the few species in which no nucleus has as yet been observed it is very probable that nuclear material is present in some form; the nucleus not only is essential to the life of the individual, but plays the initial and chief rôle in the process of reproduction. The earlier investigators, working with their imperfect microscopes, naturally formed an erroneous conception of the structure of the Protozoa, and even as late as 1838 assigned them a complete series of organs corresponding to the functions of the animal body, — a nervous system, a digestive system, etc.

The classification of the Protozoa is based for the most part on structural, *i.e.* anatomical, differences, which are due chiefly to different methods of locomotion and nutrition. Four classes are generally recognized.

## CLASS I. RHIZOPODA

The Rhizopoda (Gr. *ῥίζα*, root, and *πούς*, foot), sometimes called the Sarcodina (Gr. *σαρκώδης*, fleshlike), are found in fresh and in salt water, and are distinguished from the other groups of Protozoa by the absence of any external membrane to limit the shape of the body. Nevertheless, most of the members of this class have a pretty definite form, which is due to the presence of a skeletal structure, either external, covering more or less of the outside of the body, or internal within the protoplasm. All the Rhizopoda possess the property of protruding from the surface of their bodies rootlike, filamentous, or threadlike processes of the protoplasm, or sarcode as it is often called here, of which they are composed. These processes are known as pseudopodia, false feet; for, though they constitute the organs of locomotion, they are not permanent structures, but may in most cases be protruded from any point on the periphery of the organism and then retracted. In those species, however, where there is an external skeleton with but one or two openings the pseudopodia can obviously be extended through these openings only. The protoplasm of the Rhizopoda is generally differentiated into two regions,

—a peripheral layer, the ectosarc or ectoplasm, which is clear and homogeneous, and an inner granular portion, the entosarc or entoplasm. In this entosarc lie the nucleus or nuclei, numerous vacuoles containing fluids or food particles, together with pigment granules, minute crystals, etc. In the fresh-water species there is generally in the ectosarc a large vacuole, which disappears and reappears at more or less definite intervals of time and is therefore known as the contractile or pulsating vacuole. It appears to form in the entosarc and then move into the ectosarc. In most of the Rhizopoda there is some kind of a supporting structure or skeleton. This may be gelatinous, or chitinous, or composed of particles of sand or the shells of diatoms or other foreign bodies cemented together, or consist of more or less elaborate structures impregnated with calcium carbonate or with silica; we may best consider the details of these skeletal structures in connection with the several orders into which this class is divided.

Locomotion in the Rhizopoda is effected by means of their pseudopodia (Fig. 2), which enable them to move about with a sort of creeping motion; this is frequently spoken of as amœboid motion, the name being derived from Amœba, one of the simplest of the Rhizopoda. When the animal shows a differentiation into ectosarc and entosarc, the ectosarc takes the initiative in the formation of a pseudopodium by extending out from the surface as a threadlike or fingerlike process; into the axis of this process the entosarc passes with a streaming motion. The extension or retraction of the pseudopodia is due to stimuli produced by various agents, such as chemical substances, food particles, mechanical irritation. Often if one pseudopodium is irritated, not only does that one contract, but all the others as well, so that the stimulus must be transmitted through the protoplasmic substance of the body of the animal from one point to another. There is no definite mouth in the Rhizopoda, and hence the ingestion, or taking in of food, may occur at any point on the surface of the body. This is effected by means of the pseudopodia; these creep around the food particle, which is generally a small plant, until they completely inclose it, together with a small quantity of water, and thus a food vacuole is formed. There digestion takes place, and the undigested parts are given off at any point

on the surface. Respiration is effected internally by means of the oxygen contained in the water in the food vacuoles, and externally by the whole superficial surface of the body which is in contact with the water. The products of katabolism, *i.e.* of the breaking down of the protoplasm, the excretory products proper, are believed to pass off through the contractile vacuole (Fig. 2), when this is present, otherwise there is no definite point of expulsion.

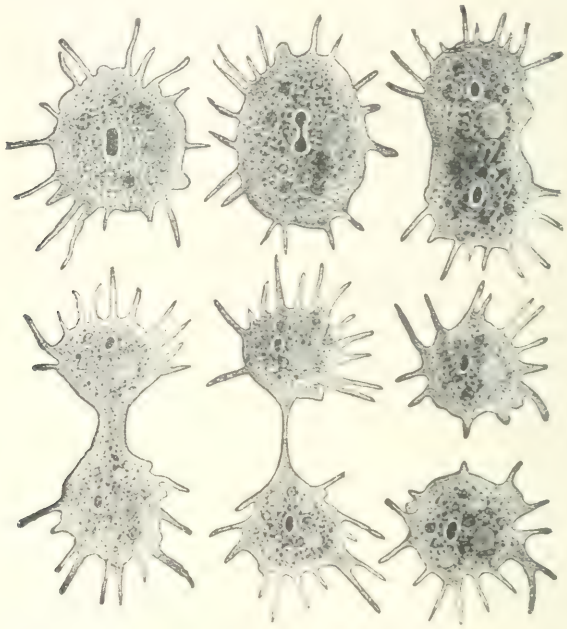


FIG. 2. *Amœba polypodia* in successive stages of division; the dark spot surrounded by a light ring is the nucleus; the light spot is the contractile vacuole. (After F. E. Schulze, from Parker and Haswell's Manual.)

The processes of reproduction are not well known in all the Rhizopoda. Simple division has been observed in all the orders (Fig. 2); the nucleus divides by direct or indirect division, and then the protoplasm divides. If there is a contractile vacuole, it remains in one of the two individuals produced, and a new one forms in the other; if there are two contractile vacuoles, one goes to each individual. Typical budding also occurs, the new Rhizopoda being smaller than the older or parent individual. Finally, spore formation attending en-

cystment is characteristic for certain groups (Fig. 3). These spores sometimes have an amœboid movement; sometimes they have a rather long, delicate, threadlike appendage, a protoplasmic process called a flagellum. This is capable of rapid vibration and functions as an organ of locomotion; such spores are said to be flagellate. In some cases two individuals may fuse with one another before encysting, but just how much significance should be attached to this process — here called conjugation — it is difficult to say.

Encystment is not always followed by spore formation and may have no connection with reproduction. Thus some of the Rhizopoda secrete a cyst around themselves after they

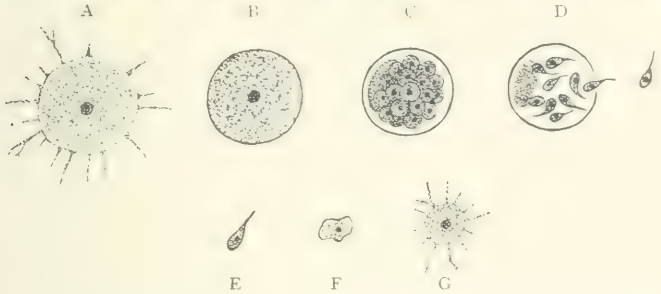



FIG. 3. *Pseudospora*, parasitic in the cells of fresh-water algæ. A, the adult individual as it exists within the plant-cell; B, encysted; C, protoplasm dividing into spores, with a residual body; D, flagellate spores escaping from cyst, leaving residual body behind; E, flagellate spore as it makes its way into a new plant-cell; F, G, development of the spore into the amœboid form of the adult. (From Delage and Hérouard's Traité de Zoologie.)

have ingested a large amount of food, and when digestion is completed they emerge from the cyst. Or encystment may occur when the surroundings of the animal are unfavorable, as when there is a scarcity of food or of moisture; thus the individual remains protected until a more favorable season.

The class Rhizopoda may be divided conveniently into three orders, omitting the Mycetozoa, sometimes placed here, which we have already considered.

### Order 1. Foraminifera

The Foraminifera (Lat. *foramina*, holes, and *ferre*, to bear) are mostly marine Rhizopoda, although there are not a few fresh-water representatives. They creep along the bottoms of quiet

pools or of the ocean, though some are found near the surface. The pseudopodia may be either blunt processes, not greatly attenuated, or long and filamentous and often anastomosing with one another by means of lateral processes. In many of the Foraminifera pseudopodia may be formed at any point on the surface of the body, but when several appear near one point there results a movement of the whole animal in that direction. Thus when the animal is moving we may speak of an anterior end, that which is in advance, and a posterior end, and it has been observed that the nucleus and the contractile vacuole lie near the posterior end. When the animal is at rest, however, it becomes impossible to make this distinction.

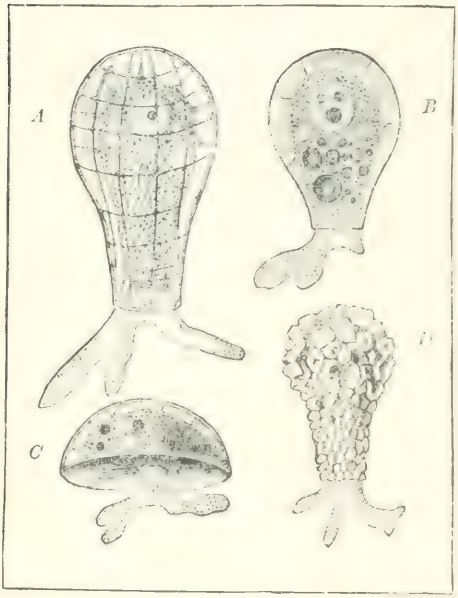



FIG. 4. *A, Quadrula symmetrica; B, Hyalosphenia lata; C, Arcella vulgaris; D, Difflugia pyriformis.* (After Schulze and Wallich, from Parker and Haswell's Manual.)

The order derives its name from the fact that the skeletons or shells are in many cases pierced by numerous minute holes through which the pseudopodia may be protruded. A skeleton is not always present, however, and some of the skeletons have only one large opening for the protrusion of the pseudopodia, and no minute pores. The shell may consist of a secreted membrane of chitin, or it may be merely a gelatinous secretion in which small particles of sand, diatoms, etc., have become embedded, or it may be composed of a secretion of calcium carbonate, and this is true of most of the marine Foraminifera. In a very few cases the shell is siliceous.

Of those that are naked, *i.e.* without skeletons, the fresh-water genus, Amœba (Fig. 2), contains characteristic examples. They

exhibit blunt, non-anastomosing pseudopodia, a clear ectosarc with its contractile vacuole, and a granular entosarc containing vacuoles and a nucleus. The fresh-water Difflugia (Fig. 4) furnishes common examples of shells made up of particles of sand

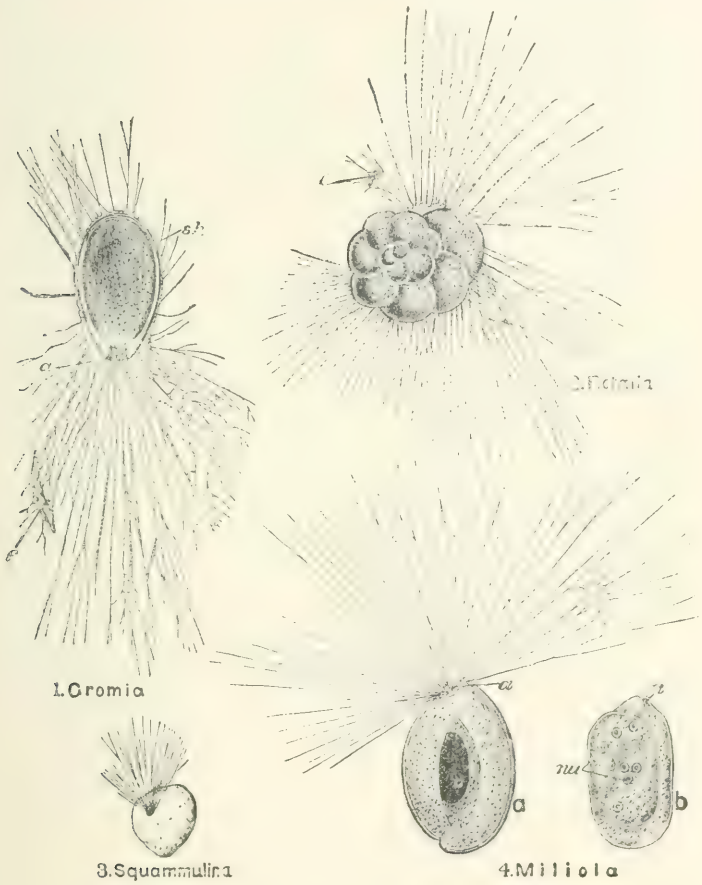



FIG. 5. Various **Foraminifera**. *a*, aperture of shell; *f*, food particles; *nu*, nucleus; *sh*, shell; in 4: **a**, the living animal; **b**, killed and stained. (From Bütschli's Protozoa and Claus' Zoology.)

and other foreign bodies, such as the shells of diatoms, cemented together. There is a good deal of diversity of shape in these shells, which have one large opening through which the pseudopodia are protruded. The pseudopodia are like those of the Amœba. There are some Foraminifera, however, having shells

resembling those of Difflugia, but the pseudopodia, which are fine and anastomosing, may be protruded between the foreign particles of which the shell is composed. The chitinous shells are well illustrated by the fresh-water Arcella (Fig. 4),

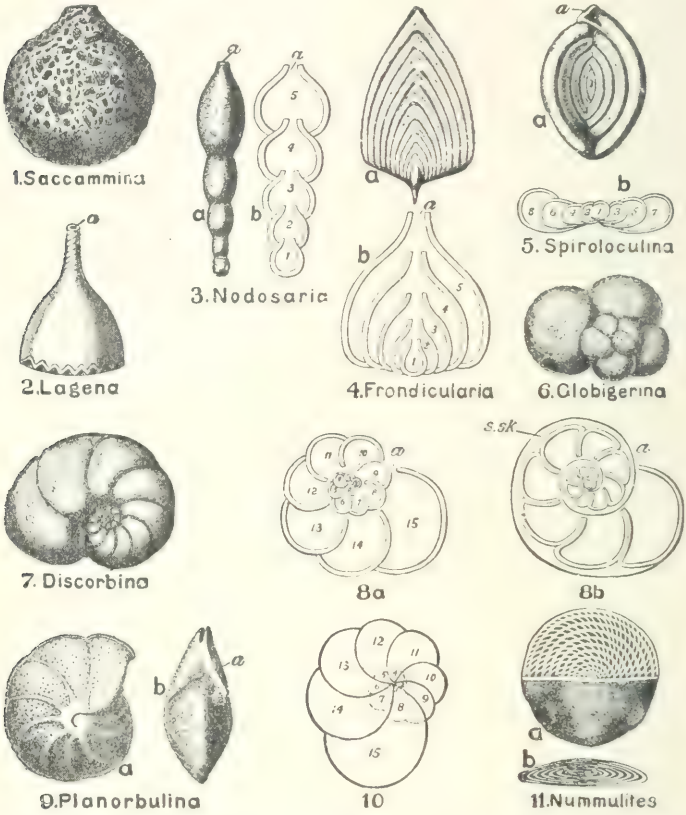



FIG. 6. Shells of **Foraminifera**. *a*, aperture of shell; 1–15, successive chambers, 1 being in each case the initial chamber and hence the oldest. In figures 3, 4, and 5, **a** is a surface view, and **b** a section; 8**a**, diagram of a coiled shell without supplemental skeleton; 8**b**, with supplemental skeleton, *s.sk*; 10, with overlapping chambers; 11**a**, the upper half in horizontal section, the lower half in surface view; 11**b**, in vertical section. (After Carpenter, Brady, and Bütschli.)

with its blunt pseudopodia, and by Gromia (Fig. 5), with its fine anastomosing pseudopodia; in the latter genus the protoplasm extends over the outer surface of the shell in a thin layer, so that the skeleton thus comes to lie internally. The calcareous shells are the most numerous and the most beau-

tiful. They may consist of a single chamber as in the spherical Orbulina, which possesses numerous fine pores and one large opening; or there may be several or even a large number of chambers, connecting with one another but joined in the most varied fashion, end to end, side by side, in a spiral, a helix, and so on (Fig. 6). It is these shells which are so abundant at the bottom of the ocean, where they constitute a conspicuous layer known as Globigerina ooze, because of the large number of Globigerina shells (Fig. 6) which it contains.

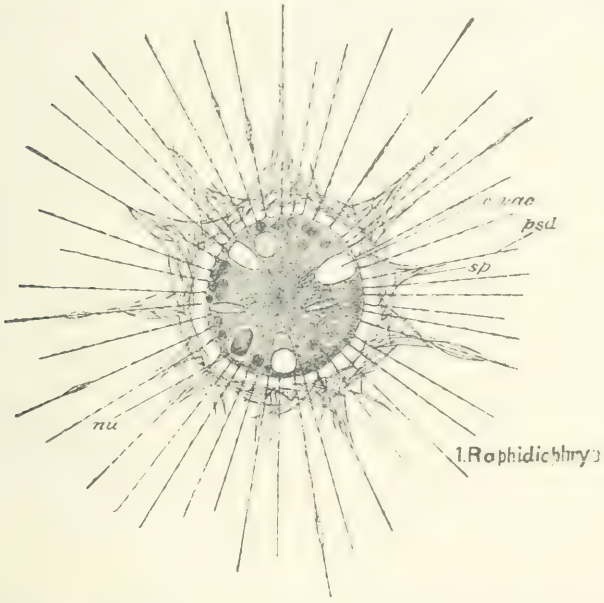



FIG. 7. A **Heliozoon**. *c.vac*, contractile vacuole; *nu*, nucleus; *psd*, pseudopodia; *sp*, skeletal spicules. (From Bütschli's Protozoa.)

These calcareous shells are also abundant as fossils and in fact constitute about three fourths of all the fossil Protozoa. The chalk formations of Europe contain many species, and the Nummulitic limestone of the Pyrenees is composed largely of various kinds of Nummulites (Fig. 6), having a flat, disklike shell with complicated, spirally arranged chambers; these shells may have a diameter of five or six centimeters. In the United States, formations containing Foraminifera are very abundant in South Carolina, Virginia, and many other states.

### Order 2. Heliozoa

The Heliozoa (Gr. ἥλιος, sun, and ζῷον, animal) constitute an extremely small group which is confined to fresh water. They are readily distinguished from the fresh-water Foraminifera by their pseudopodia, which are permanent, delicate structures radiating in all directions from the more or less spherical body, — hence the name of the order (Fig. 7). In the axis of each pseudopodium is a delicate, firm, supporting rod extending toward the center. The protoplasm contains one or more

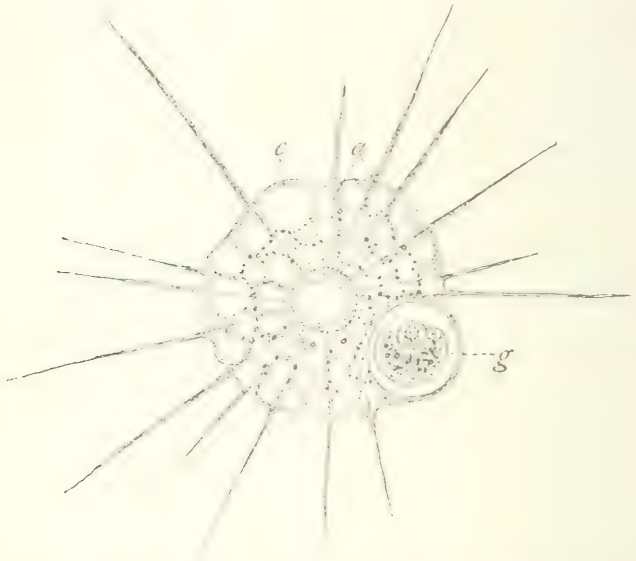



FIG. 8. *Actinophrys sol*, a Heliozoön. (After Grenacher, from Calkins' Proto[illegible]

nuclei and one or more contractile vacuoles, and often pigment granules or chlorophyll bodies as well as numerous non-contractile vacuoles. The latter are often very numerous and form a definite peripheral layer to the body of the heliozoön (Fig. 8). Aside from the axial supports to the pseudopodia, a skeleton may be entirely absent, or represented by a simple gelatinous envelope, or it may consist of a more or less elaborate structure of silica. The latter may be composed of loosely interlacing, simple, siliceous spicules (Fig. 7), or it may consist

of a sphere elaborately pierced with holes and attached to a stalk (Fig. 9).

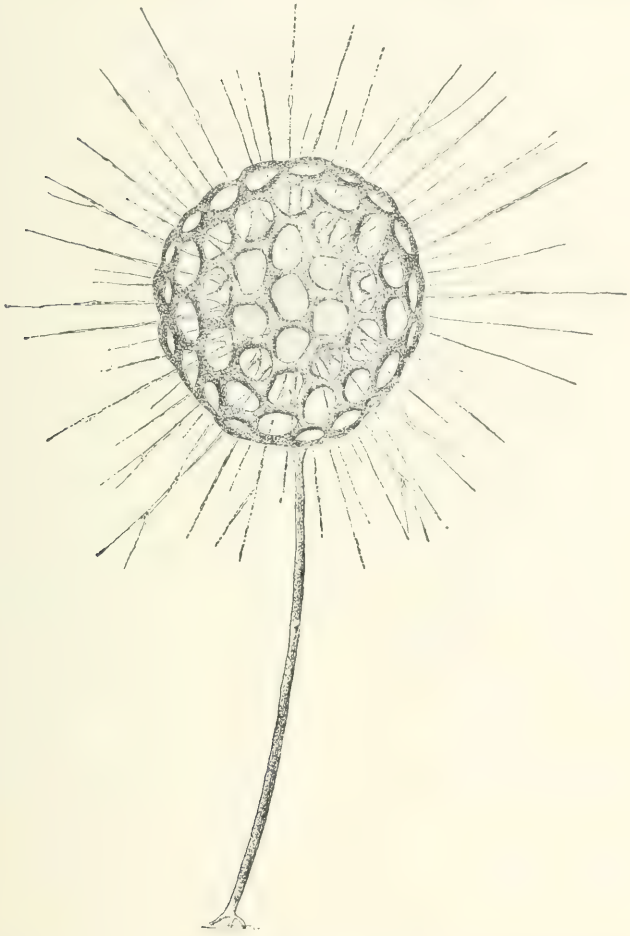


FIG. 9. *Clathrulina elegans*, a stalked Heliozoon. (After Greeff, from Calkins' Protozoa.)

### Order 3. Radiolaria

The Radiolaria (Lat. *radare*, to radiate) are all marine organisms, which greatly resemble the Heliozoa, especially in the arrangement of the pseudopodia. They differ from the Heliozoa and the Foraminifera, however, in that the protoplasm is divided into two portions, an inner and an outer, by means of a

chitinous membrane or capsule pierced by holes. These two parts of the protoplasm are therefore known as the intracapsular and the extracapsular respectively. Within the capsule lies a large nucleus or several nuclei, together with oil globules, granules, vacuoles, and sometimes minute crystals. The extracapsular protoplasm is generally filled with large, globular vacuoles, non-contractile, and beyond the free surface project the radiating pseudopodia (Fig. 10). There is generally a siliceous skeleton, though not always, and this varies greatly from simple, loosely arranged spicules to very elaborate, latticework structures (Fig. 11) resembling helmets, spheres, stars, and in some cases consisting of three concentric spheres pierced by numerous openings and radiating spicules (Fig. 12). In many of the Radiolaria there occur yellowish granules in the extracapsular protoplasm, which have long been known as the "yellow cells." They are minute algæ which live with these Radiolaria in a state of symbiosis, a term applied to the intimate association of two organisms to their mutual advantage. Although, like most of the Rhizopoda, the members of this order live as separate individuals, in a few cases colonies are formed, and a number of individuals lie inclosed in a common extracapsular mass (Fig. 13). These colonies are sometimes macroscopic, being several centimeters in diameter. The reproduction of the Radiolaria, so far as it is known, differs from that of the other Rhizopoda in the method of spore formation. The spores are formed entirely in the intracapsular protoplasm;

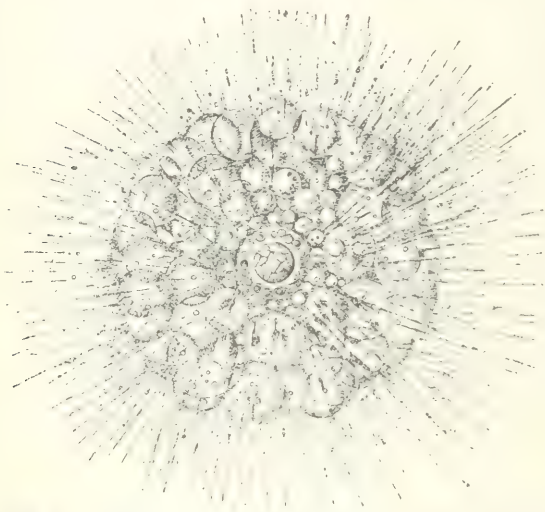


FIG. 10. *Thalassicola pelagica*, a Radiolarian. (After Haeckel, from Hatschek's Lehrbuch.)

here some individuals may produce spores which are all alike, isopores, while others produce two kinds of spores, large, macrospores, and small, microspores. These spores are all flagellate, each having a single flagellum.

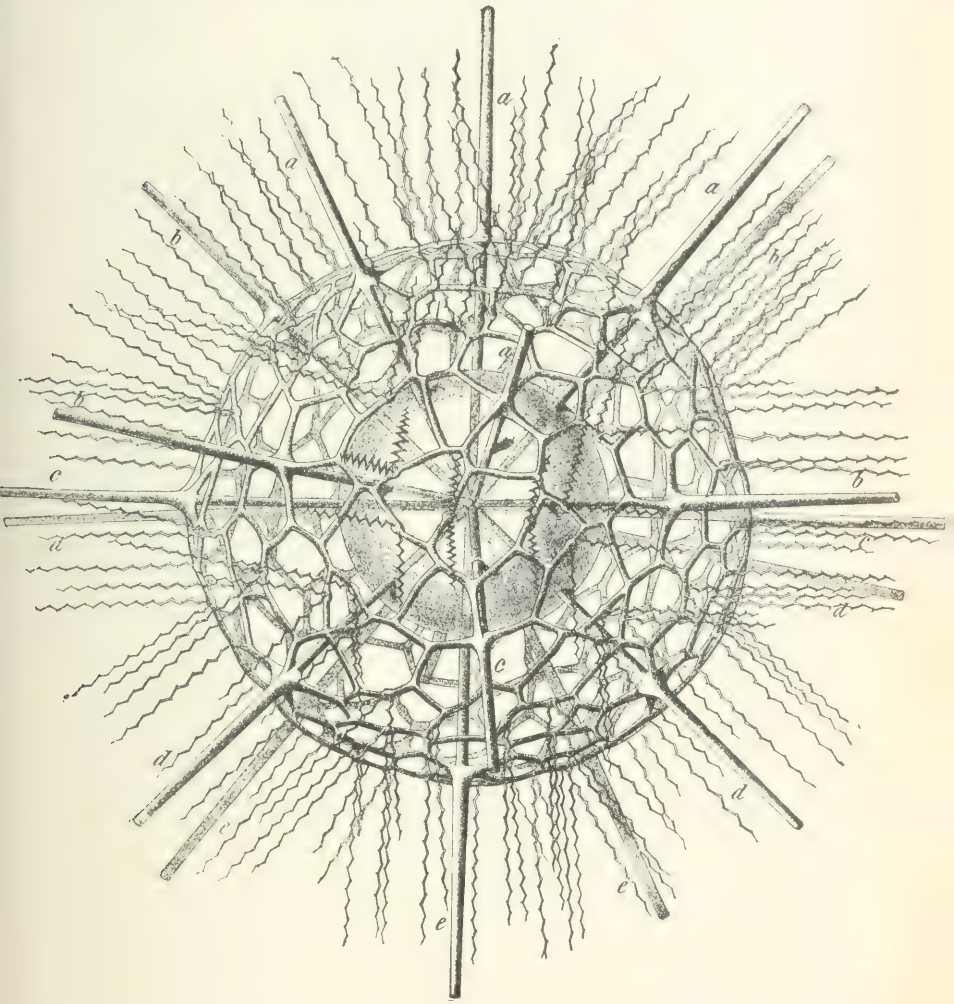



FIG. 11. *Lichnaspis giltochii*, a Radiolarian; skeleton. *a, a, a, a*, northern polar spines; *b, b, b, b*, northern tropical spines; *c, c, c, –*, equatorial spines; *d, d, d, d*, southern tropical spines; *e, e, e, –*, southern polar spines. (After Haeckel, from Calkins' Protozoa.)

The Radiolaria usually float near the surface of the ocean, but they may sink to greater depths. They constitute the larg-

est order of living Rhizopoda, and include about a quarter of the fossil Protozoa. As fossils they are found along the coast of the

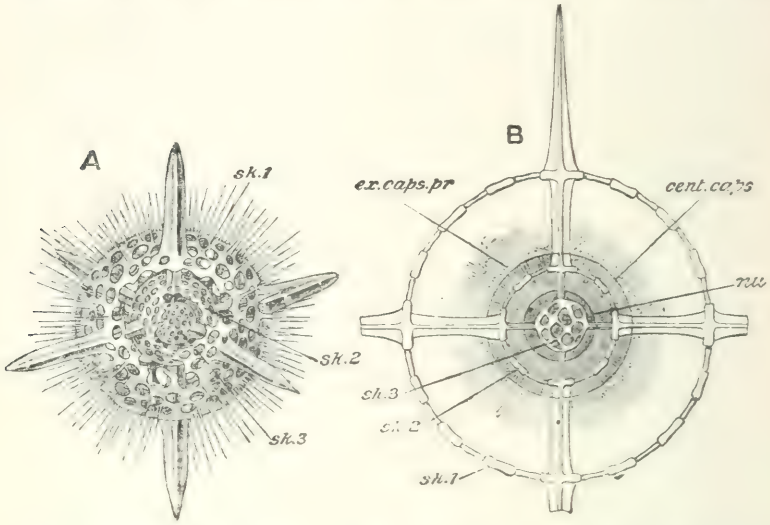



FIG. 12. *Actinomma asteracanthion*. A, with portions of the two outer spheres of the shell broken away; B, a section. *cent. caps*, central capsule; *ex. caps. pr*, extracapsular protoplasm; *nu*, nucleus; *sk.*1, outer, *sk.*2, middle, *sk.*3, inner, sphere of skeleton. (After Haeckel and Hertwig, from Parker and Haswell's Manual.)

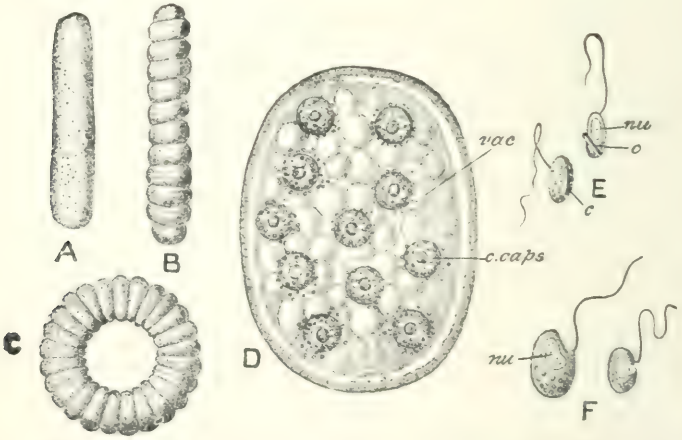



FIG. 13. *Collozoum inerme*. A, B, C, three forms of the entire colony, natural size. D, a small colony enlarged, showing numerous central capsules and vacuoles. E, spores containing crystals. F, macrospore and microspore. *c*, crystals; *c.caps*, central capsules; *nu*, nucleus; *vac*, vacuoles. (After Hertwig and Brandt, from Parker and Haswell's Manual.)

Mediterranean, in Virginia and Maryland, in the Barbados, and most extensively in the Nicobar Islands, where they contribute rock formations from three hundred to six hundred meters thick.

## CLASS II. SPOROZOA

The Sporozoa (Gr. *σπόρος*, seed, and *ζῶον*, animal) constitute a small group of parasitic Protozoa, all living within the cells or the cavities of other animals, and in this respect they differ from all other classes of Protozoa; for though there are some parasites in each class, all the members of the Sporozoa are parasitic. They reproduce exclusively by spore formation, and from this fact derive their name. This class may be divided into five orders.

### Order 1. Gregarinida

The Gregarinida (Lat. *gregarius*, gregarious) include the largest of the Sporozoa. They are generally more or less elongated, and possess a granular entosarc containing a single nucleus but no vacuoles, and a clear ectosarc with an outer cuticula, a delicate membrane through which fluids pass to nourish the protoplasm within. The members of this class are divided into two groups, the one represented by Monocystis (Fig. 14), which occurs in the male reproductive organs of the earthworm, the other known as Gregarina or Porospora (Fig. 15), which lives in the intestines of various insects, the lobster, crayfish, and similar animals. Monocystis is like the type just described. Reproduction begins by the formation of a cyst, which may contain one or two individuals. Within the cyst a large number of spindle-shaped bodies, the so-called spores, are formed by the division of the nucleus or nuclei, and then the contents of each of these spores divides into a number of crescentic bodies, each of which becomes a new individual. Gregarina may be distinguished from Monocystis by the fact that the body is divided

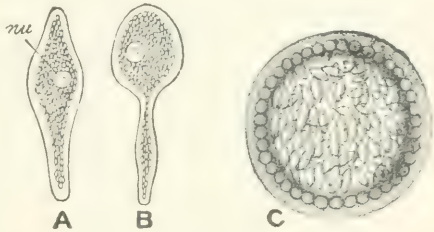



FIG. 14. *Monocystis agilis*. A, B, different shapes assumed; C, cyst containing spores. (From Parker and Haswell's Manual.)

into two regions, a smaller anterior, and a larger posterior, — the latter contains the nucleus. Cysts are formed as in Monocystis, and within, a number of spindle-shaped bodies called pseudonavicellæ are formed; but a part of the contents of the cyst always remains undivided and is known as the residual body. The contents of each pseudonavicella then divides into from two to eight crescentic spores, with a residual body as before,

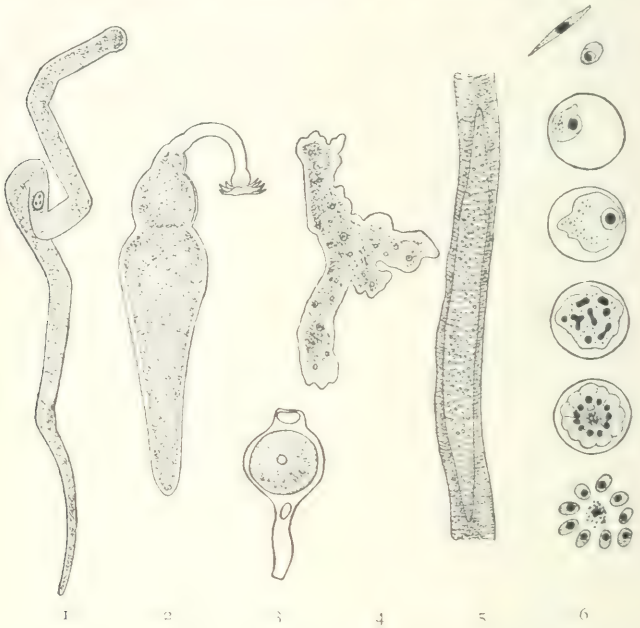



FIG. 15. Various **Sporozoa.** 1, *Porospora* (*Gregarina*) *gigantea*, from the intestine of the lobster; 2, *Actinocephalus oligacanthus*, young individual with hooks; 3, *Eimeria falciformis*, in an epithelial cell of the intestine of the mouse; 4, *Myxidium lieberkühnii*, amœboid, from the urinary bladder of the pike; 5, *Sarcocystis*, in a muscle of the pig; 6, *Plasmodium*, the malarial parasite; successive stages of development. (1–5, after Bütschli; 6, chiefly after Grassi.)

and each spore becomes a new individual. The adults live in the intestinal canal and are capable of slow locomotion by means of a general contraction of the body; the young embed themselves within the cells which line the intestine, and only when mature do they come out into the canal, often remaining for some time in connection with the cells by means of an organ of attachment frequently provided with hooks (Fig. 15, 1 and 2).

### Order 2. Coccidiida

The Coccidiida (Gr. *κόκκος*, a berry) are extremely small Sporozoa, spherical or ovoid, and live within the cells of the higher animals, particularly in the liver and the intestine. There each individual secretes a cyst about itself, and afterward, the contents of the cyst divides into spores, each of which gives rise to crescentic young (Fig. 15, 3). These parasites are of importance to physicians, as they sometimes occur in man and produce serious diseases.

### Order 3. Myxosporida

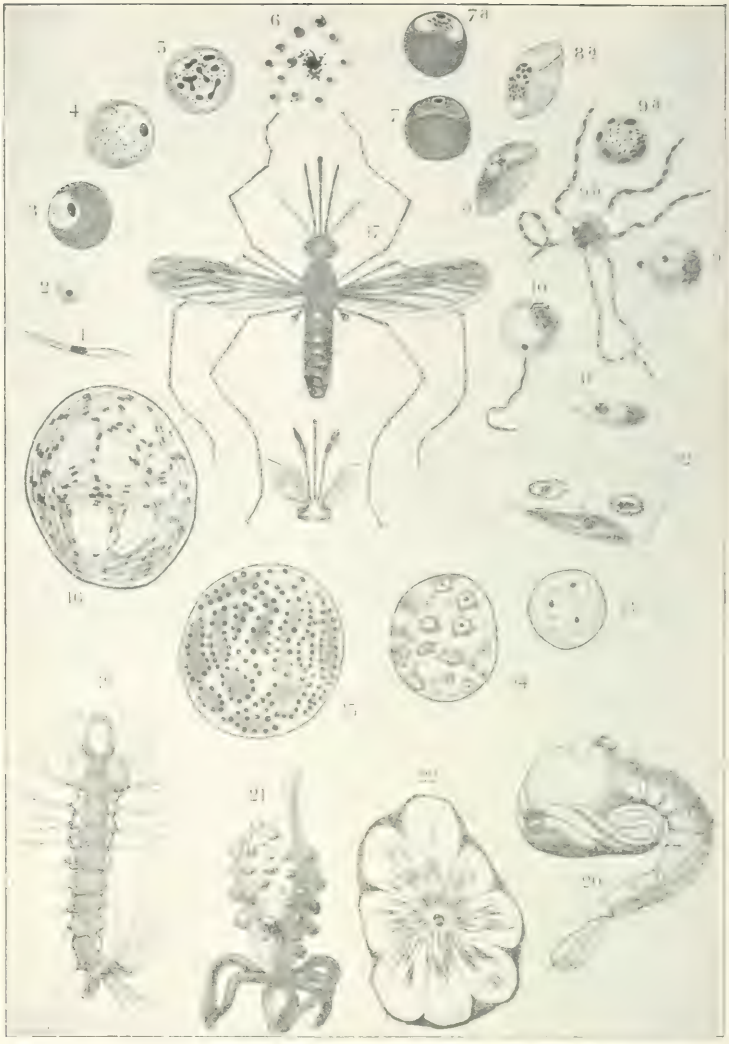
The Myxosporida (Gr. *μύξα*, mucus) differ from the other Sporozoa in being amœboid. They exhibit a clear ectosarc and a granular entosarc, the latter containing many nuclei (Fig. 15, 4). Reproduction is by spore formation attending encystment; both the method of formation and the spores themselves are rather complex. The Myxosporida are parasitic for the most part on fishes, and are found in the skin and in many of the internal organs.

### Order 4. Sarcosporida

The Sarcosporida (Gr. *σάρξ*, flesh) occur in the voluntary muscles of some of the higher animals, where they exist as elongated cysts. The walls of these cysts are radially striated, and contain a granular mass of protoplasm, which eventually forms a number of spores, and these give rise to numerous crescentic young. One of the most common representatives of the order is Sarcocystis (Fig. 15, 5), which is found in the pig; it does not appear to affect the health of its host.

### Order 5. Hæmosporida

The Hæmosporida (Gr. *αἷμα*, blood) are minute animals living within the blood-cells, especially the red blood-cells, of higher animals. The young individuals enter the cells, grow to maturity, deriving their nourishment from the cell they inhabit, and then break up into a number of sporelike bodies or young, which pass into other blood-cells (Figs. 15 and 16). These animals are of great importance to the physician, for they are the parasites to which the malarial or intermittent fevers are due.



17–22. 1, sporozoite, or form introduced by a mosquito bite into human blood; 2, the same free in the blood; 3–5, changes which it undergoes in the red blood-cell; 6, merozoites or spores formed by division, with the attendant destruction of the blood-cell; this cycle, 2–6, may be repeated many times, but eventually [illegible] develop in the blood-cells into sexual forms; 7, 8, 9, development of a macrogamete or female element; 7a, 8a, 9a, 9b, development of microgametes or male element; 10, conjugation of a macrogamete and a microgamete; 11, oökinet resulting from this conjugation; it must now enter the mosquito; 12, oökinet at base of two cells in wall of mosquito's stomach; 13–16, transformation within the mosquito of an oökinet into an oöcyst filled with sporozoites; the sporozoite must then enter the human blood; 17–22, see Fig. 220. (After Leuckart-Chun's wall-chart, from Sedgwick's Sanitary Science.)

## CLASS III. MASTIGOPHORA

The Mastigophora (Gr. *μάστιξ*, a whip, and *φέρω*, to bear) are often known as the Flagellata (Lat. *flagellum*, a whip), but at present the latter term is usually restricted to the first order under this class. They are distinguished from the other Protozoa by the fact that each individual possesses one or more delicate, elongated, protoplasmic processes, the flagella, which function as the chief organs of locomotion. They are found in fresh and in salt water, living singly and in colonies, and some exhibit relationships either structural or functional with the Rhizopoda and with plants.

### Order 1. Flagellata

The Flagellata exhibit great diversity of form and are to be distinguished from the rest of the Mastigophora chiefly by the absence of those structures which are characteristic of the other orders. There is always a flagellum at the anterior end of the animal, and frequently two, and others may be present on other parts of the body.

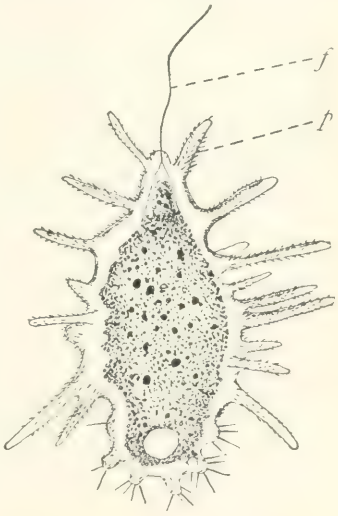



FIG. 17. *Mastigamoeba aspera*. *f*, flagellum; *p*, pseudopodium. (After F. E. Schultze, from Calkins' Protozoa.)

The shape of the body may be more or less irregular (Fig. 17), spherical, ellipsoid, ovoid, or elongated (Fig. 18), or colonies may be formed, spherical (Figs. 19, 20, and 21), or branched in various ways (Figs. 19 and 22), the latter often remarkably beautiful. There is generally a single nucleus, a contractile vacuole, and often a bright red pigment spot, which is supposed to be sensitive to light. In some, numerous colored granules are present, either greenish, due to chlorophyll, or reddish. Many Flagellata are naked, *i.e.* the body is not bounded by any definite membrane; others have a thin cuticula, and some

secrete a chitinous, flask- or vase-shaped shell about themselves, through the opening of which the body may be protruded. Those containing chlorophyll granules often have a cell wall of

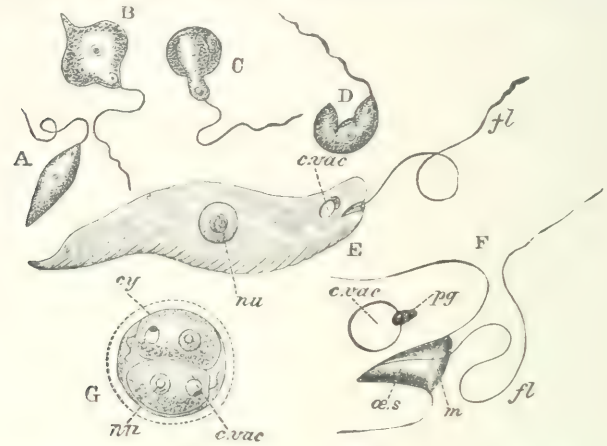



FIG. 18. *Euglena viridis*. A–D, various shapes assumed during locomotion; E, a single individual more highly magnified; F, the anterior end of the body still further enlarged; G, two individuals in a cyst. *c.vac*, contractile vacuole; *cy*, cyst; *fl*, flagellum; *m*, mouth; *nu*, nucleus; *œs*, œsophagus; *pg*, pigment spot. (After Kent and Klebs, from Parker and Haswell's Manual.)

cellulose. In many cases there is no definite mouth; this is true of some of the naked species, where the food consists purely of nutritive fluids, which are absorbed directly into the

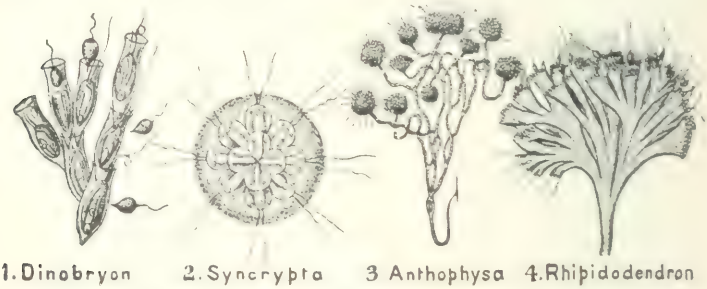



FIG. 19. Variously shaped colonies of **Flagellata**. (From Parker and Haswell's Manual.)

protoplasm, and also of those which are colored and inclosed in a continuous membrane of cellulose; here the nutriment is obtained from the water and assimilated precisely as in the case of plants. But often there is a definite mouth situated at the

anterior end of the animal near the base of the flagellum, and leading into a funnel-shaped tube, the gullet or œsophagus, as

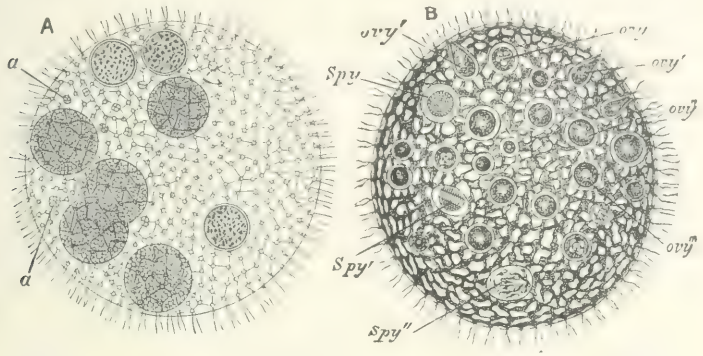



FIG. 20. *Volvox globator*. A, colony containing several daughter colonies; B, colony during spore formation. *a*, early stages in the formation of new colonies; *ovy*, developing macrospores; *spy*, developing microspores. (After Cohn and Kirchner, from Parker and Haswell's Manual.)

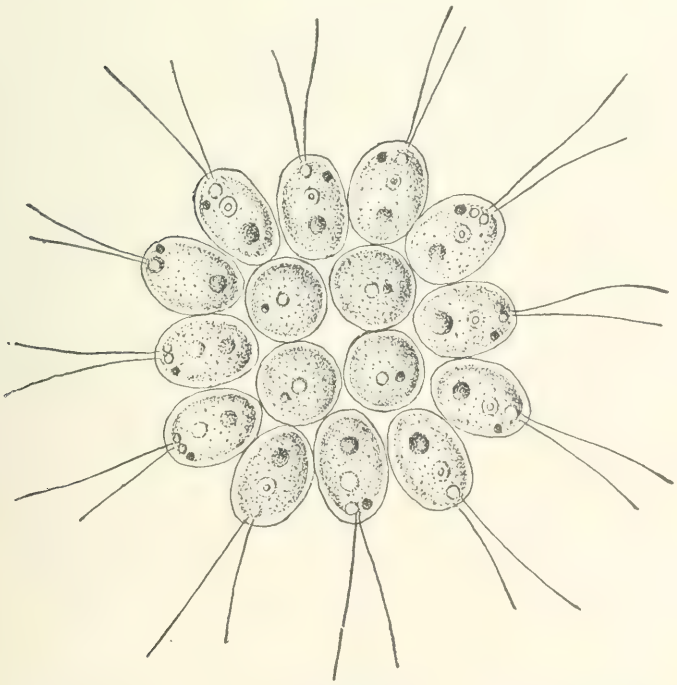


FIG. 21. *Gonium pectorale*, a colony of Flagellata. (After Stein, from Calkins' Protozoa.)

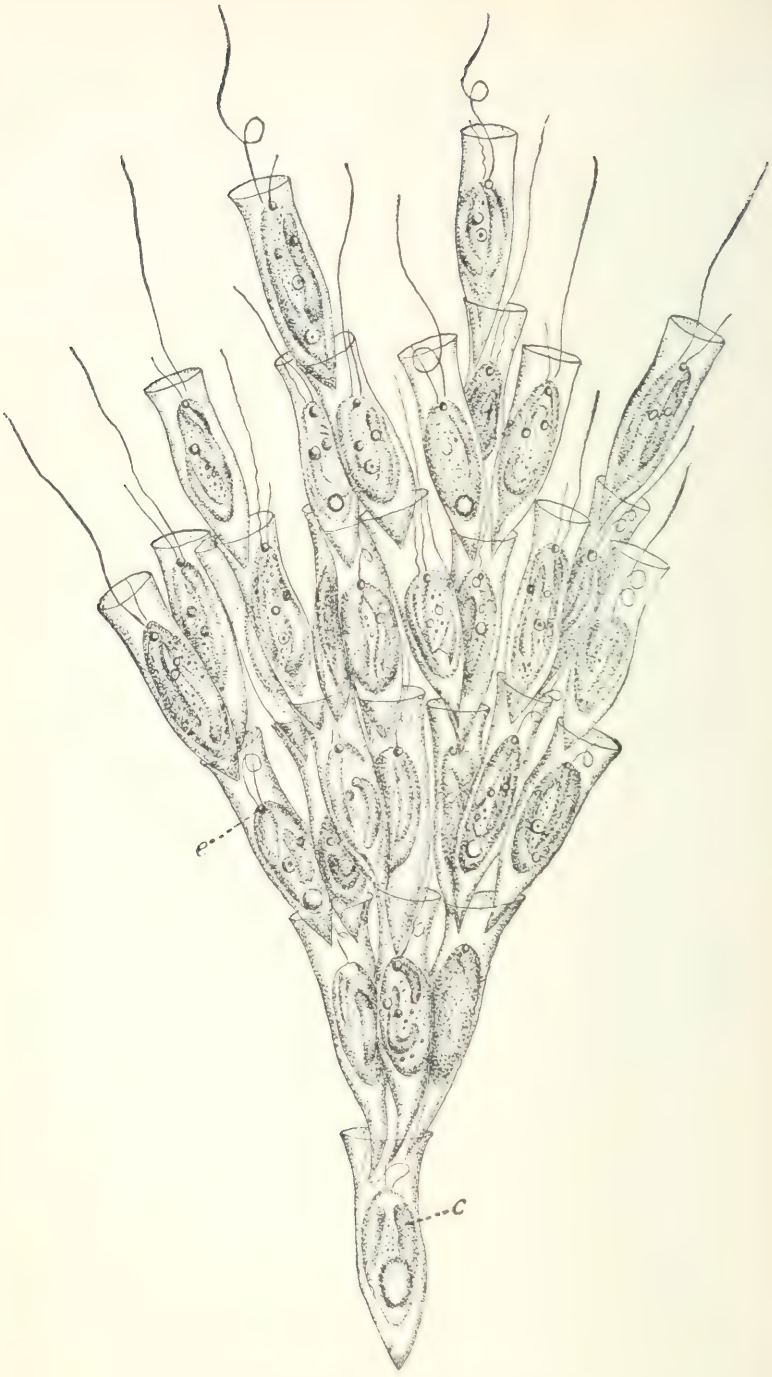



FIG. 22. *Dinobryon sertularia*. *c*, chromatophore; *e*, eye-spot.
(After Stein, from Calkins' Protozoa.)

in the fresh-water Euglena (Fig. 18). The flagella serve not only for locomotion, but also for procuring food. Undigested substances usually leave the body near the posterior end, but there is no permanent opening like the mouth.

Reproduction generally takes place by simple division, either during the active condition of the individual or after it has secreted a cyst about itself; in the latter case division may result in two, but often in several, new individuals. In the colonial Flagellata each individual in some genera divides a number of times and becomes a colony, so that division results in as many new colonies as there were individuals in the old. In other cases, as, for example, in Volvox (Fig. 20), which consists of a hollow sphere, the wall being composed of a single layer of individuals, certain cells enlarge and divide, forming new colonies which come to lie inside the hollow sphere; eventually they are set free by the death and disintegration of the parent colony. In some Flagellata there is a more complex method of reproduction, which closely resembles sexual; this is well illustrated by Volvox again (Fig. 20). Some cells in the colony greatly enlarge and become macrospores, others divide a large number of times and become microspores; these two kinds of spores fuse with one another, and then division results in a new colony.

### Order 2. Choanoflagellata

The Choanoflagellata (Gr. χοάνη, a funnel) are readily distinguished by the presence of a protoplasmic collar or cup, which surrounds the base of the flagellum, and both the collar and the flagellum are contractile. There is a single, spherical nucleus and one or two contractile vacuoles. Some are naked, others have a chitinous, cuplike shell, as in some of the Flagellata (Fig. 23), and many are raised on stalks. These animals may live singly (Fig. 23), in branched colonies (Fig. 24), or as irregular groups of individuals (Fig. 23). They occur in fresh and in salt water. Reproduction is generally by longitudinal division, but spore formation attending encystment also occurs.

### Order 3. Dinoflagellata

The Dinoflagellata (Gr. δῖνος, a whirl) generally possess two flagella, one extending freely from the anterior end of the body,

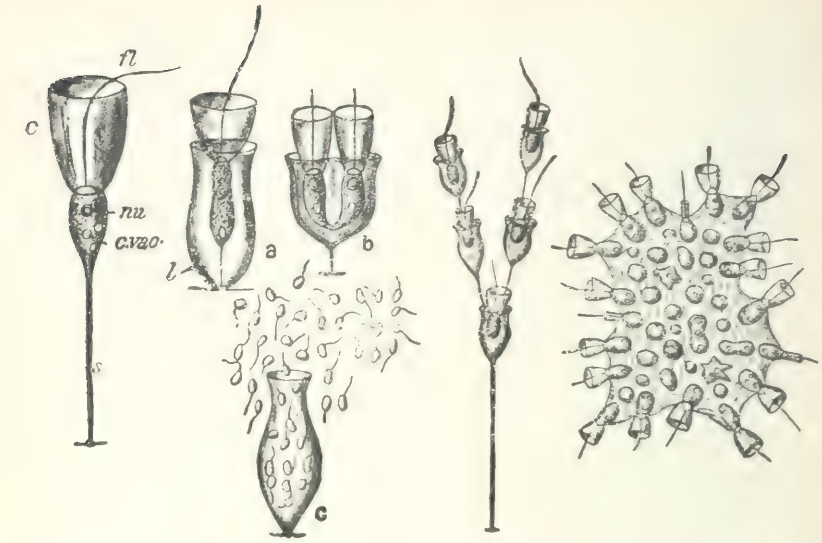



FIG. 23. Various **Choanoflagellata**. *c*, collar; *c.vac*, contractile vacuole; *fl*, flagellum; *l*, lorica or chitinous shell; *nu*, nucleus; *s*, stalk. 2b, longitudinal division; 2c, spore formation. (After Kent, from Parker and Haswell's Manual.)

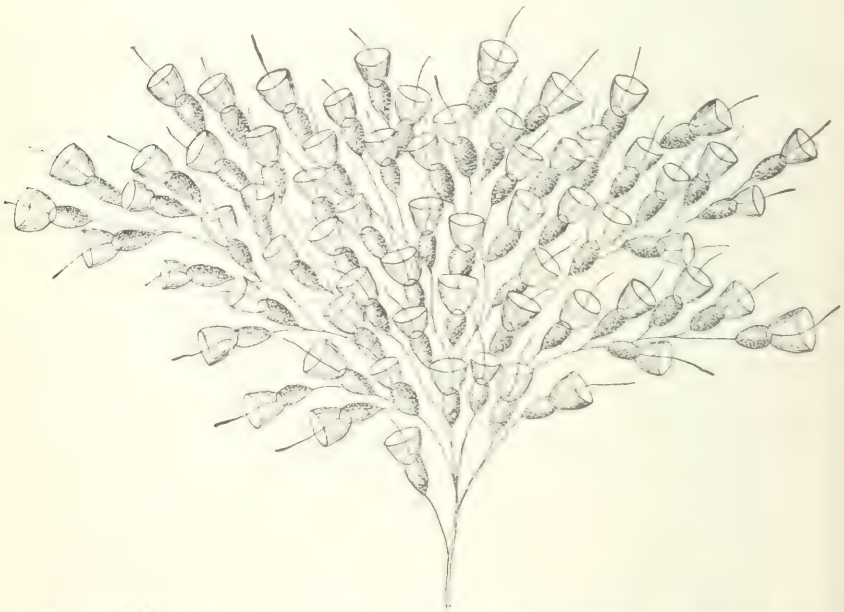


FIG. 24. *Codosiga botrytis*, a branching colony of Choanoflagellata. (After Kent from Calkins' Protozoa.)

the other lying in a groove which passes around the body transversely. There is almost always a shell of cellulose, often more or less ornamented by various kinds of projections (Fig. 25). Chlorophyll or some similar pigment is generally present, as well as a nucleus or nuclei, and a contractile vacuole. The method of nutrition in some cases is that of plants, in others, that of animals, and they reproduce by division. This order is largely marine.

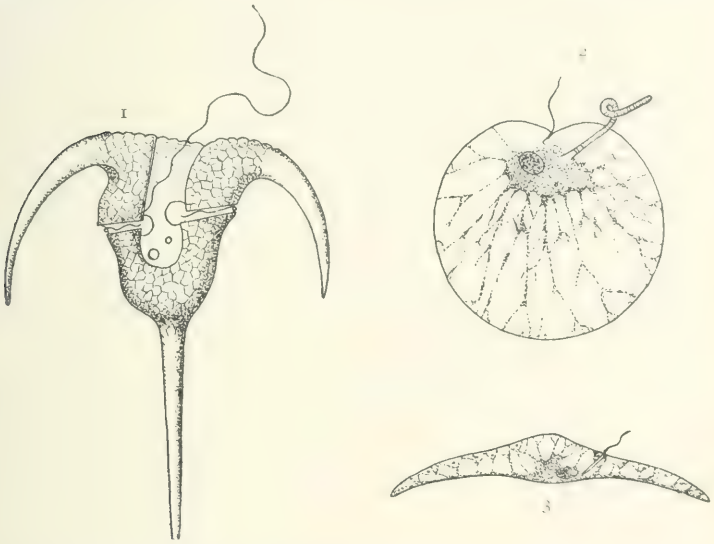



FIG. 25. 1, *Ceratium tripos*, a Dinoflagellate; 2, *Noctiluca miliaris*, a Cystoflagellate; 3, *Leptodiscus medusoides*, a Cystoflagellate, in section. (1, from Bütschli's Protozoa; 2, chiefly after Cienkowski; 3, after Hertwig, from Delage and Hérouard's Traité de Zoologie.)

### Order 4. Cystoflagellata

The Cystoflagellata (Gr. κύστις, a bag) are represented by only two genera, Noctiluca and Leptodiscus, both marine, and having a cystlike structure. Noctiluca (Fig. 25) is more or less spherical, bounded by a thin cuticula; the protoplasm is greatly vacuolated, appearing as a granular mass surrounding the nucleus, with a network of fine threads extending to the periphery. There is a mouth with a short flagellum, and near by a second flagellum much larger than the first, known as the tentacle, which is marked by transverse bands. Noctiluca possesses the

property of emitting light at night and is one of the animals which produce the phosphorescence of the ocean. Reproduction takes place by simple division and also by spore formation; in the latter case the protoplasm collects about the nucleus, which divides many times, and a mass of budlike spores is formed, projecting above the surface (Fig. 26). These spores then become free and swim about by means of a flagellum. This process of spore formation may or may not be preceded by a temporary union of two individuals, that is, by conjugation.

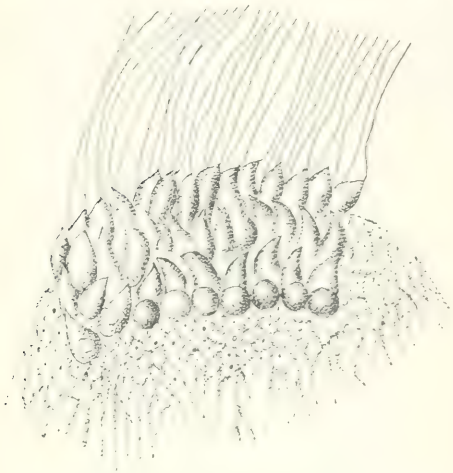


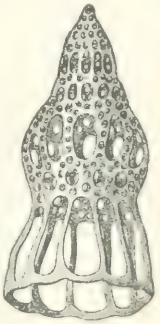
FIG. 26. *Noctiluca miliaris*. Spore formation. (After Robin, from Calkins' Protozoa.)

Leptodiscus (Fig. 25) is two or three times as broad as Noctiluca, and has a similar structure except that the tentacle is absent, and the general form of the body is like a watch crystal or a meniscus.

## CLASS IV. CILIATA

The Ciliata (Lat. *cilium*, an eyelash) are often known as the Infusoria (Lat. *infusorium*) because some species are particularly abundant in certain infusions; the term *Infusoria* is also used at times to include both the Mastigophora and the Ciliata. The Ciliata are the most highly differentiated of all the Protozoa, and are distinguished from the other classes by the presence of numerous, delicate processes, hairlike and motile, the cilia, which are always present during some part of the life of the individual; they serve both for locomotion and for procuring food. These animals occur for the most part in fresh water, though some are marine. They are found in great abundance in stagnant pools and are generally free-swimming individuals, although not a few are attached to plants and other

objects, often by means of a stalk, which may or may not be contractile. Among the attached species are some that live in colonies. The body is always bounded by a delicate membrane or cuticula, within which the protoplasm is clearly differentiated into an ectosarc and entosarc. In a few cases a chitinous shell is developed, but this is extremely rare (Fig. 27). Cilia project beyond the surface of the body and vary greatly in number and distribution, occurring frequently in longitudinal bands; we shall consider their arrangement under the several orders. The ectosarc is more or less modified, often highly so, and may contain fine contractile threads, which allow the animal to alter its general form. In a few cases, occurring chiefly in the first order mentioned below, minute capsules lie in the ectosarc, each containing a delicate, coiled thread, which may be projected when the animal is irritated; these structures are known as trichocysts. In the granular entosarc lies the nucleus, which presents the most varied shapes, — spherical, ellipsoid, ovoid, elongated, and straight or wavy, U-shaped, moniliform, or very irregular. This nucleus is often spoken of as the macronucleus, since we find nearly always one or more smaller nuclear structures lying near it, and these are called micronuclei. There may be one, two, or many contractile vacuoles, and there are frequently one or more contractile radial canals, which empty into them. Pigment granules are often present in the entosarc and sometimes chlorophyll granules. There is generally a permanent mouth in all the Ciliata where the cilia are present throughout life, and this leads into an œsophagus. The undigested food particles pass off near the posterior end of the body.



1.Dictyocysta

FIG. 27. Shell of *Dictyocysta*, one of the **Ciliata**. (From Bütschli's Protozoa.)

The most common method of reproduction is by transverse division; in some species budding occurs and in some spore formation. In some cases, after reproduction by division has gone on for some time, a temporary union of two individuals takes place, accompanied by an interchange of micronuclear substance. After this conjugation, the two individuals separate and reproduction by division continues. The micronucleus

plays the most important rôle in conjugation, and in some cases the conjugation is permanent, *i.e.* the two individuals completely fuse with one another. The division of the class into orders depends chiefly on differences in the size and distribution of the cilia.

### Order 1. Holotricha

The Holotricha (Gr. ὅλος, whole, and θριξ, a hair) differ from the other orders of the Ciliata in that they have cilia of nearly

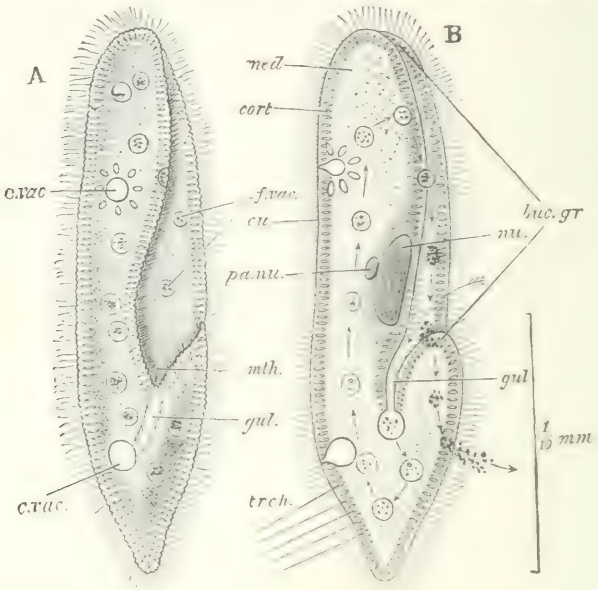



FIG. 28. *Paramœcium caudatum*. A, the appearance of the living animal from the oral surface; B, the same individual in optical section; the arrows indicate the course of the food particles. *buc. gr*, buccal groove; *cort*, ectosarc, containing trichocysts; *cu*, cuticula, with projecting cilia; *c.vac*, contractile vacuole; *f.vac*, food vacuole; *gul*, gullet or œsophagus; *med*, entosarc; *mth*, mouth; *nu*, macronucleus; *pa. nu*, micronucleus; *trch*, discharged trichocysts. (From Parker's Biology.)

equal length distributed over the entire body. Paramœcium (Fig. 28) is a common example of this order; it is very abundant, occurring in hay infusions and in stagnant water.

### Order 2. Heterotricha

The Heterotricha (Gr. ἕτερος, different, and θριξ, a hair) have cilia over the whole surface of the body, but in the region of the

mouth there is always a ring of cilia much longer than the rest; Stentor (Fig. 29), a green, trumpet-shaped, fresh-water animal, belongs to this order. It is visible to the naked eye, and we often see several of them swimming about together, attached at their posterior ends.

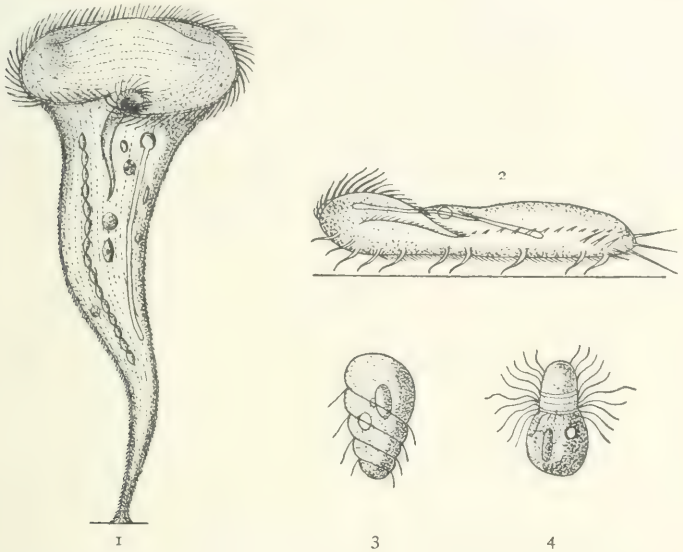



FIG. 29. 1, *Stentor polymorphus;* 2, *Stylonichia mytilus*, lateral aspect; 3, *Acineta fœtida*, young individual; 4, *Podophrya fixa*, young individual. (After Kent.)

### Order 3. Peritricha

The Peritricha (Gr. *περί*, around, and *θρίξ*, a hair) have the cilia confined to a spiral band around the anterior end of the body. At the posterior end there is often, but not always, a stalk containing a contractile band by means of which the animal may be drawn toward the object to which it is attached. Vorticella (Fig. 30) is a characteristic representative of the order, occurring in both fresh and salt water. We also find colonies (Fig. 31).

### Order 4. Hypotricha

The Hypotricha (Gr. *ὑπό*, under, and *θρίξ*, a hair) are oval, more or less flattened Ciliata, having one side of the body practically free from cilia, while the other, which may be called the ventral side, possesses cilia and groups of cilia fused together.

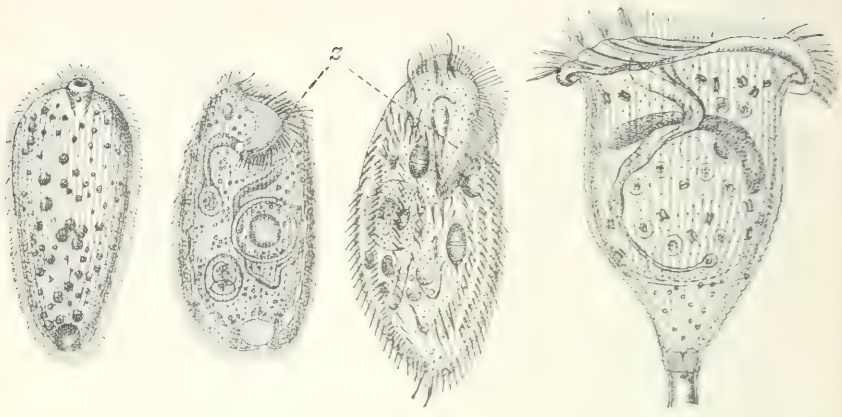



FIG. 30. Various **Ciliata.** A, *Prorodon teres*, one of the Holotricha; B, *Climacostomum virens*, one of the Heterotricha; C, *Pleurotricha grandis*, one of the Hypotricha; D, *Vorticella umbellaria*, one of the Peritricha. *z*, adoral zone of cilia. (After Bütschli, from Calkins' Protozoa.)

FIG. 31. *Epistylis umbellaria*, a colony of Peritricha; conjugation. *M*, macrogamete; *m*, microgamete. (After Greeff, from Calkins' Protozoa.)

thus forming bristlelike structures, which the animal uses as feet for walking. Near the mouth is a sharply defined band of cilia. The best-known member of this order is Stylonychia (Fig. 29).

### Order 5. Suctoria

The Suctoria (Lat. *sugere*, to suck) differ from the other Ciliata in having no cilia in the adult condition. They are

FIG. 32. *Dendrosoma radians*, a colony of Suctoria. *n*, nucleus. (After Kent, from Calkins' Protozoa.)

attached individuals, with a cuticular membrane and with or without a stalk, and possess a number of delicate processes, the tentacles, provided at the free end with a sort of sucking disk (Fig. 32). The Suctoria feed on other animals, chiefly other

Ciliata, which they kill and absorb through their tentacles. The young individuals are generally formed by budding, and unlike the adult are well ciliated and swim about freely (Fig. 29). Eventually they settle down on some object, become attached, the cilia disappear, and the tentacles of the adult develop. Representatives of this order are found in fresh and in salt water.

# CHAPTER IV

## SUBKINGDOM II. METAZOA

## TYPE II. CŒLENTERATA

All animals except the Protozoa may be placed under the subkingdom Metazoa (Gr. *μετά*, after, and *ζῶον*, animal), the higher animals, as they are usually called. They are all multicellular organisms, and the cells are always differentiated so as to form at least two layers, an outer and an inner, known

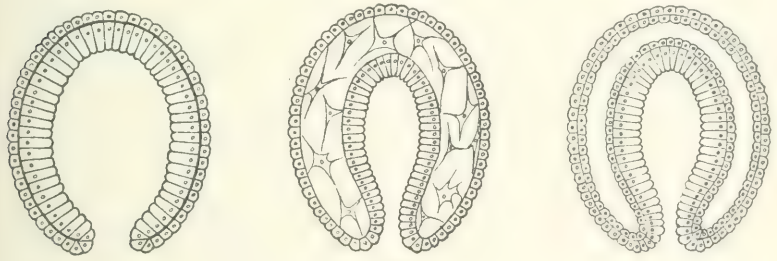


Fig. 33. Diagrams illustrating the different types of cell arrangement in the Metazoa. A, outer layer of cells, *ectoderm;* inner layer of cells, *entoderm;* between the two, *basement membrane.* B, outer layer of cells, *ectoderm;* inner layer of cells, *entoderm;* between the two, *mesenchyme;* basement membrane and mesenchyme are often called together, *mesoglœa.* C, outer layer of cells, *ectoderm;* innermost layer of cells, *entoderm;* layer in contact with the ectoderm, *somatic mesoderm;* layer in contact with the entoderm, *splanchnic mesoderm;* between the two, the *body-cavity* or *cœlom.* (Drawn by the author.)

respectively as the ectoderm and the entoderm, which differ in function as well as in position. These two layers are never in direct contact, but are separated by a third structure, which exhibits several types of differentiation. In its simplest condition it is merely a gelatinous or fibrous secretion, which may be called a basement membrane. In other cases there is a gelatinous secretion containing cells, usually stellate or spindle-

shaped, and such a structure is known as a mesenchyme. Finally this middle structure may consist of a definite layer or

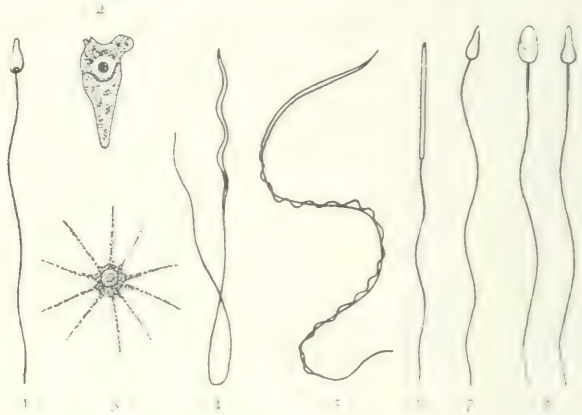


FIG. 34. Various forms of spermatozoa. 1, medusa; 2, nematode; 3, crustacean; 4, ray or skate; 5, salamander; 6, frog; 7, monkey; 8, man, two views. (From Claus and Sedgwick's Text-book and Parker and Haswell's Textbook.)

layers of cells and is then called a mesoderm. A cavity generally appears within the mesoderm, thus dividing it into two

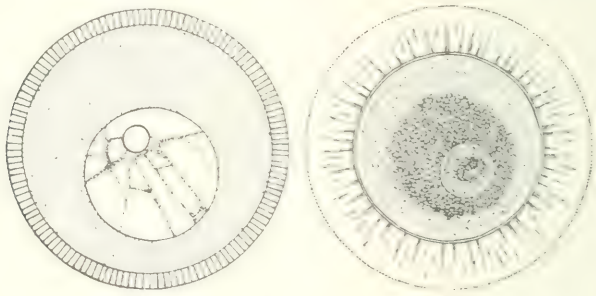


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FIG. 35. 1, ovum of sea-urchin, showing the radially striated egg-membrane, the granular protoplasm within, and in the center the large nucleus containing the spherical nucleolus and granular network. (After Hertwig.) 2, human ovum, showing the clear, radially striated membrane, here called the zona pellucida, the finely granular protoplasm within, and the coarser yolk or nutritive granules in the midst of which the nucleus lies. (After Nagel.)

layers, one adjoining the ectoderm, the other in contact with the entoderm; the cavity is known as the body-cavity or cœlom (Fig. 33).

In addition to this differentiation of the cells into layers, there is usually also a differentiation into somatic or body-cells and germ- or reproductive-cells; the latter are of two kinds, the male cells or spermatozoa (Fig. 34), and the female cells or ova (Fig. 35); so that while reproduction occurs in some cases by division and by budding, it generally takes place by means of fertilized ova, a process which does not occur typically in the Protozoa, but is suggested in such types as Volvox, where the macrospores and microspores may be compared to ova and spermatozoa respectively.

There are a few simply organized animals whose structure is such that their position in the system of classification is very doubtful. An intermediate subkingdom, the Mesozoa, is sometimes made for them, but they are of little importance for the elementary student (Fig. 36).

We shall divide the Metazoa into six types, though these are far from being of equal importance, and several of them are necessarily divided into subtypes.

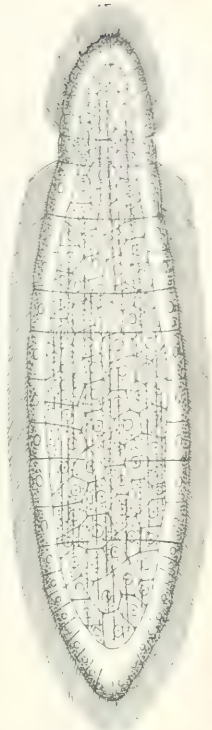

FIG. 36. *Rhopalura giardii*, ♀, one of the Mesozoa; parasitic in the body-cavity of Ophiuroidea; greatly enlarged. (From Parker and Haswell's Text-book.)

## TYPE II. CŒLENTERATA

The Cœlenterata (Gr. κοῖλος, hollow, and ἔντερον, intestine) constitute the simplest type of the Metazoa. In their least modified condition, the body is saclike, with an opening at one end. The wall of the sac consists of ectoderm on the outside, entoderm on the inside, and between these a basement membrane or a mesenchyme, — a true mesoderm does not occur in this group, and thus a body-cavity or cœlom is absent. The body contains a single cavity, bounded by the entoderm, and this is generally known as the cœlenteron: it functions as a digestive tract. Some of the cells of the body are modified into muscle-cells, others into nerve-cells, and others

into germ-cells, while in the more highly organized members of the type there are organs of sight and hearing. Very many of the Cœlenterata are attached to foreign objects, and often form large colonies by budding.

While the animals belonging to this type present the characteristics mentioned above, they form, nevertheless, two groups which are otherwise pretty distinct from one another; these groups constitute the subtypes.

## SUBTYPE I. PORIFERA

The Porifera (Lat. *porus*, a pore, and *ferre*, to bear), or sponges, are, in their simplest condition, hollow cylinders attached at one end and open at the other; the opening is known as the osculum (Fig. 37). The walls of the cylinder are pierced by a large number of canals, which put the central cavity in communication with the outside; the openings of these canals on the surface are called the lateral pores. The exterior of the sponge is covered with ectoderm, the interior and the lateral canals in part are lined with entoderm. In some species the whole entoderm consists of collared, flagellate cells, precisely like the individuals of the Choanoflagellata; and in other species these collared cells are confined to the canals or parts of the canals (Fig. 38). The water, bearing particles of food, passes through the pores and canals, and the flagellate cells

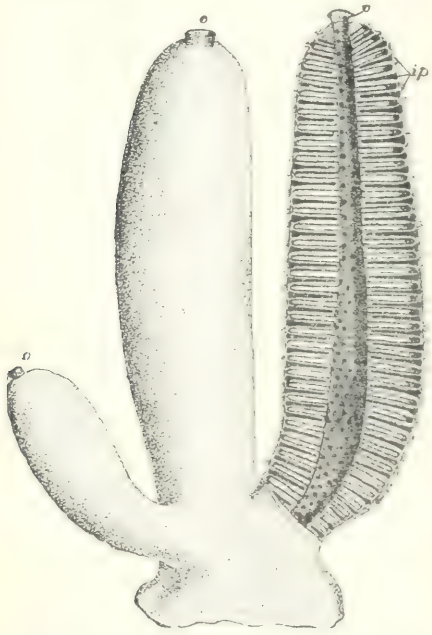


FIG. 37. *Sycon gelatinosum*. Portion of a colony, enlarged; one individual [illegible] showing [illegible] through the wall. [illegible] of the lateral pores. (After Parker and Haswell.)

take in the food in precisely the same way as do the Choanoflagellata; the water then passes out through the osculum. It was the presence of these collared, flagellate cells that led zoölogists some years ago to classify the sponges as colonies of flagellate Protozoa. We now know that this view was incorrect, for there is not only an ectoderm and an entoderm, but between is a well-developed mesenchyme, in which is formed the skeleton, which is present in almost all sponges. This skeleton is secreted by the mesenchyme-cells and may consist of calcium carbonate, or of silica, or of spongin, a substance which is chemically allied to silk, — it forms a fibrous network. In some sponges we find both siliceous spicules and spongin fibers.

There are several methods of reproduction. In many sponges budding occurs, and the individuals thus produced often fuse with one another, forming huge colonies (Fig. 39). This fusion may be so extensive that it is impossible to determine the number of individuals in the colony; in other cases the colony is of such a form that the indi-

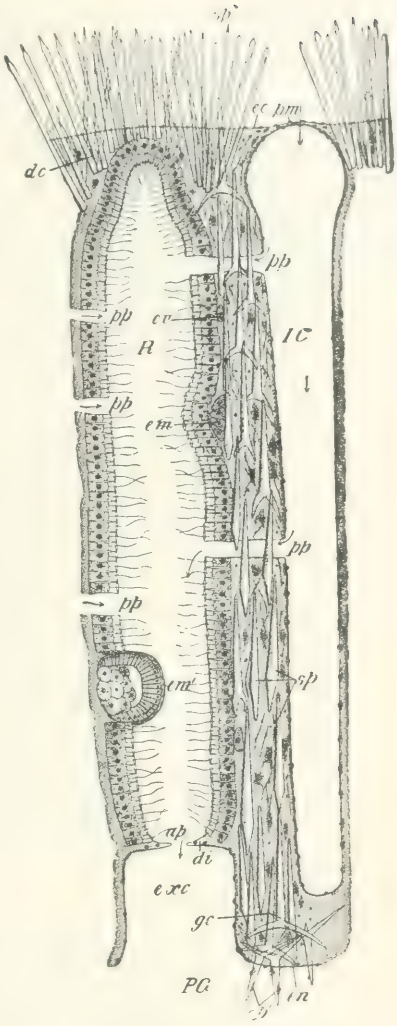


FIG. 38. *Sycon gelatinosum.* Transverse section through a portion of the body-wall. The arrows indicate the course of the water from the outside to the central cavity or cœlenteron. *ap*, apopyle; *dc*, dermal cortex; *di*, diaphragm; *ec*, ectoderm; *em*, young embryo; *em'*, older embryo; *en*, entoderm: *exc*, excurrent passage; *gc*, gastral cortex; *IC*, incurrent canal; *ov*, ovum; *PG*, cœlenteron or paragastric cavity; *pm*, pore membrane; *pp*, prosopyles; *R*, radial canal; *sp*, triradiate spicules; *sp'*, oxeote spicules; *sp''*, tetraradiate spicules. (After Parker and Haswell.)

viduals composing it may be distinguished by noting the number of large openings, or oscula, of which one belongs to each animal (Fig. 40). There is another form of budding, which may be called internal budding; it occurs typically in some fresh-water sponges. Some of the mesenchyme cells collect into groups,

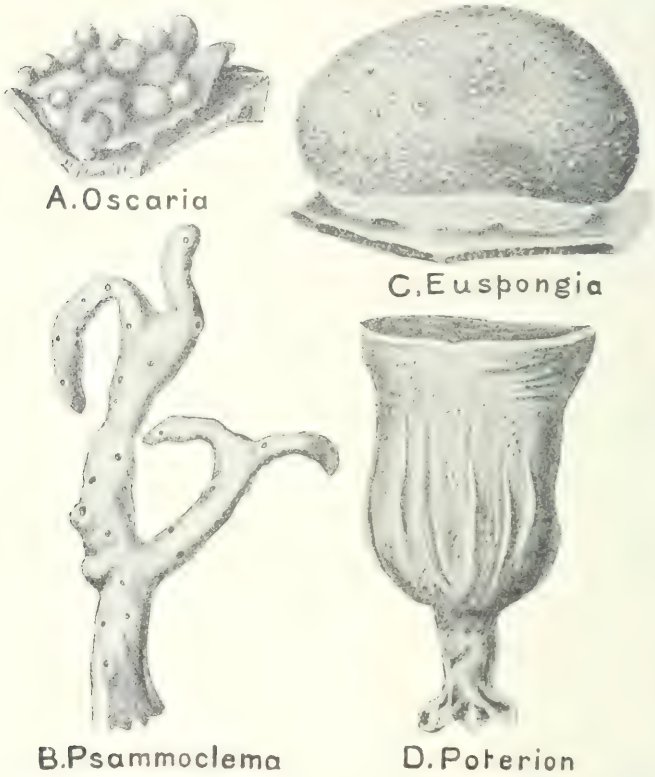


FIG. 39. Various forms of sponges. A, incrusting, with numerous rounded elevations; B, ramifying, subcylindrical; C, toilet sponge, massive, with broad base; D, Neptune's cup, vase-shaped. (After Vosmaer, from Parker and Haswell's Text-book.)

and each group secretes a cyst about itself, forming what is called a gemmule (Fig. 41). The rest of the sponge dies, and after a time the cells emerge from the gemmule and develop into a new sponge. Reproduction also takes place by means of fertilized ova. The germ-cells develop from mesenchyme cells, and the ova are fertilized while still within the mesenchyme; there they develop in part, and the young,

which are free-swimming, ciliated, and called larvæ because so different from the adult (Figs. 42 and 42 bis), pass out and eventually become attached and give rise to a new sponge colony. Many sponges are hermaphroditic, *i.e.* each individual produces both ova and spermatozoa, but cross fertilization generally takes place, since the male and the female germ-cells do not mature at the same time in the same individual.

FIG. 40. *Sycongelatinosum.* Entire colony, natural size. (After Parker and Haswell.)

The sponges are all aquatic and for the most part marine, — there are a few fresh-water species. In the ocean they occur at all depths, some being found in the tide pools along the shore, others in the deep sea, and they have a very wide distribution, for we find them in all the waters of the world. They vary almost as much in color as in shape, some being bright green, others pale green, others yellow, orange, dark violet, or white, and many have a peculiar and

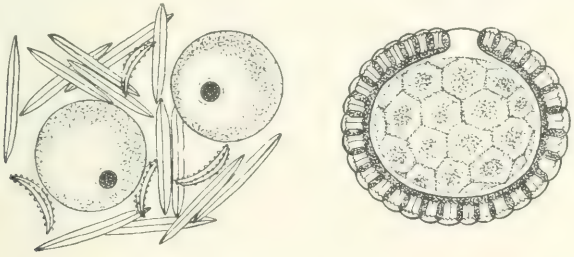

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FIG. 41. Gemmulæ of fresh-water sponges. 1, *Spongilla lieberkühnii*, external view of two gemmulæ surrounded by the sponge-spicules; 2, *Spongilla fluviatilis*, a single gemmule more enlarged, seen in section, showing the thick wall with its radial siliceous supports, the amphidiscs and the single opening closed by a membrane; within is the mass of germinal cells. (From a Leuckart-Nitsche wall-chart; permission of Dr. C. Chun.)

characteristic odor. As we have already noticed, the adult sponge is always attached, and its lack of motion caused the sponges for a long time to be classified as plants. Some sponges, however, live attached to other animals, but not as parasites, for they derive no nourishment from them, but rather in a state of symbiosis, as, for example, where they are found

living on the shells of crabs; the crab walks about, and thus the sponge acquires a new supply of water and food, while the plant-like appearance of the sponge protects the crab from its enemies. The association is, however, not very intimate, and is perhaps more properly called commensalism. Numerous fossil sponges have been found, but they are all members of groups still in existence; they are most abundant in the chalk formations.

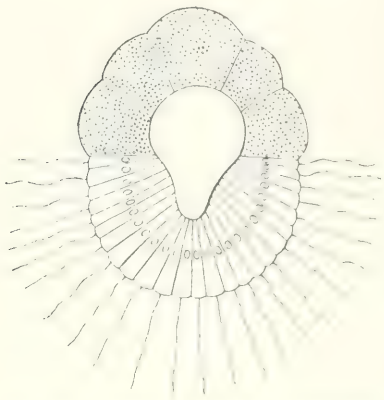


FIG. 42. *Sycandra raphanus*, a calcareous sponge; larva in the blastula stage; seen in optical section; enlarged. (After F. E. Schulze, from Hatschek's Lehrbuch.)

The sponges may all be included under one class, bearing the same name as the subtype; and this class may be divided into four orders, based on differences in the skeleton.

## CLASS PORIFERA

### Order 1. Myxospongiæ

The Myxospongiæ (Gr. *μύξα*, mucus, and *σπογγιά*, a sponge) possess no skeleton whatever. They are found in the sea, incrusting stones and seaweeds, and are often brightly colored.

### Order 2. Calcispongiæ

The Calcispongiae (Lat. *calx*, lime, and *spongia*, a sponge) have a skeleton consisting of spicules of calcium carbonate; the spicules are of various forms, some needle-shaped, others triradiate or quadriradiate. These sponges are exclusively marine and are found in water of no great depth. They frequently live singly and often form small colonies a few centimeters in diameter (Figs. 43 and 40). They are usually not brightly colored, but of an inconspicuous gray or buff.

### Order 3. Ceratospongiæ

The Ceratospongiæ (Gr. *κέρας*, horn, and *σπογγιά*, a sponge) are so called because the skeleton has the appearance of horny

fibers, but it consists of spongin, and there are no spicules of silica (Fig. 39). The skeleton is most familiar as the horse-sponge, the common bath-sponge, and the silk-sponge. These sponges do not grow at great depths, — they are most common

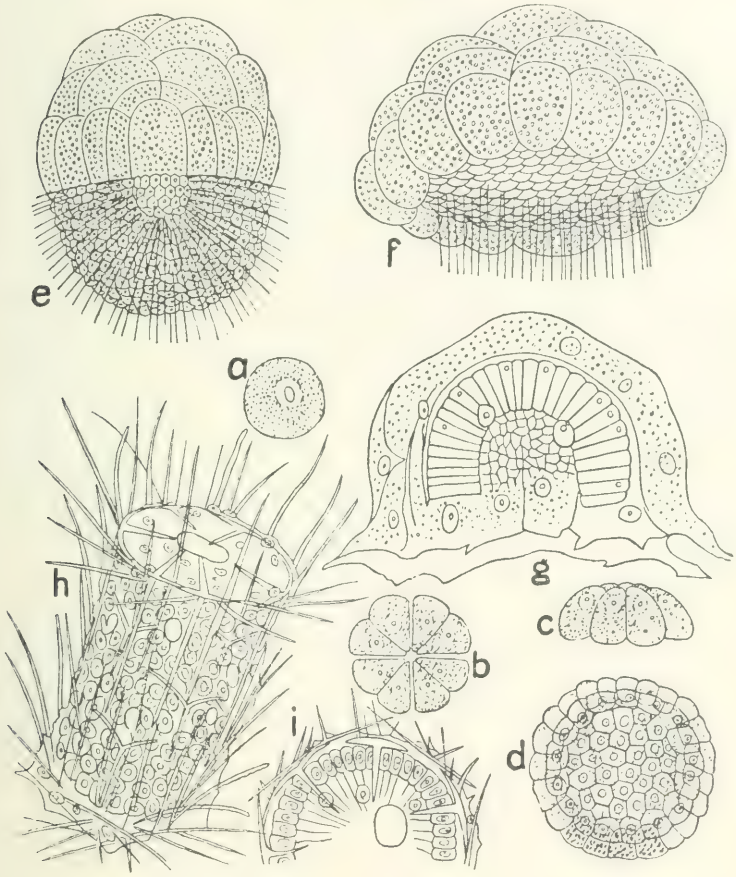



FIG. 42 bis. *Sycon raphanus*, development. *a*, ovum; *b*, *c*, ovum segmented — *b*, as seen from above, *c*, lateral view; *d*, blastula; *e*, amphiblastula; *f*, beginning of invagination; *g*, gastrula attached by its oral surface; *h*, *i*, young sponge — *h*, lateral view; *i*, as seen from above. (After Schulze, from Parker and Haswell's Text-book.)

in water less than 150 meters deep, and occur in rounded colonies. The commercial sponges generally live in water less than 60 meters deep, on rocky or coral shores, and are secured either by divers or by means of long hooks or tri-

dents. The colonies are squeezed to destroy the soft parts, which are then allowed to macerate, and the sponges are finally washed in fresh water, so that the skeleton is all that remains. The best commercial sponges come from the Mediterranean; the finest quality is from the Levant, the second best from the Adriatic, but none grow on the coasts of Italy, France, Spain, or the adjacent islands. Other sponges of not so fine a quality are obtained in the Red Sea, among the Bahamas, and off the coast of Florida.

FIG. 43. *Sycon ciliatum*. (After Hyatt, from Parker and Haswell's Manual.)

### Order 4. Silicispongiæ

The Silicispongiæ (Lat. *silex*, flint, and *spongia*, a sponge) possess a skeleton of siliceous spicules and often in addition spongin fibers. The spicules are often very elaborately formed, and the entire skeleton is sometimes extremely beautiful, as in the Venus' flower-basket (Fig. 44), which lives in the deep sea. This is a very large group of sponges, and they have a wide distribution; here belong the common fresh-water species, many which occur in the tide pools, and others at almost all depths of the ocean.

## SUBTYPE II. CNIDARIA

The Cnidaria (Gr. *κνίδη*, a nettle) are of the same general type or plan as the Porifera, — *i.e.* the body is a sac, whose wall consists of ectoderm, entoderm, and a basement membrane or mesenchyme. To this sac there is a single opening, which is called the mouth, for all the food passes through it to the cœlenteron, since there are no pores or canals through the walls, like those in the Porifera. The mouth, then, of the Cnidaria is not analogous to the osculum of the Porifera. The characteristic from which the Cnidaria derive their name is the presence of certain modified ectodermal cells, known as nettle-cells (Fig. 45). These cells possess a flask-shaped cavity, called a nematocyst, which contains a long, delicate thread, coiled up, and when the surface of the animal is irritated by some foreign body or substance, this thread is shot out violently, and thus serves as an organ of defense against enemies and for capturing small animals

which may serve for food. Somewhat similar structures have already been described as occurring in some of the Ciliata.

In the Cnidaria we find two kinds of individuals very different in appearance, but fundamentally not so unlike one another. The one is attached, and the general shape of the body is that of a hollow cylinder, closed at the attached end, with the mouth at the opposite end, which is surrounded by one or more rings of slender, fingerlike processes known as tentacles. Such individuals are called polyps. The other kind is free-swimming and disc- or bell-shaped, with tentacles around the margin of the bell; these are known as medusæ (Fig. 46). Some of the Cnidaria live in fresh water but by far the greater number are marine, and include such animals as are known popularly as the Portuguese man-of-war, sea-anemones, jellyfishes, and corals.

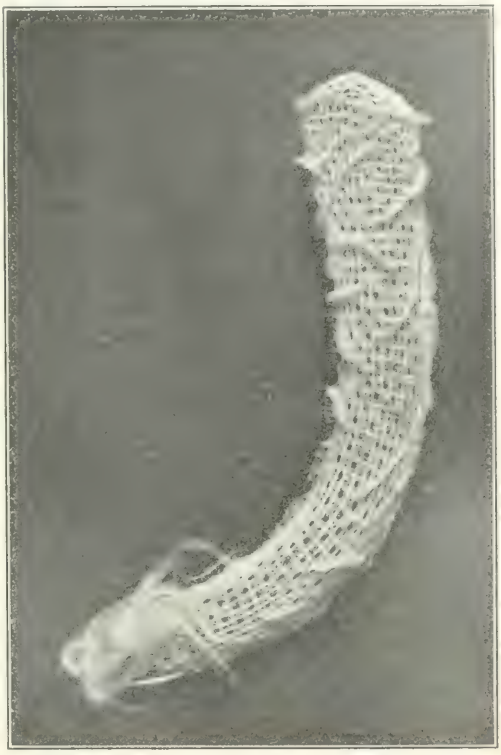


FIG. 44. *Euplectella*, skeleton, siliceous. (Photographed from specimen, by the author.)

## CLASS I. HYDROZOA

The Hydrozoa (Gr. ὕδωρ, water, and ζῷον, animal) are found in fresh and in salt water, and include both polyps and medusæ. The polyps conform to the typical Cnidarian described above. The ectoderm and entoderm are separated by a basement

membrane, and come in contact with one another at the mouth. Below the mouth there are one or two rings of tentacles. The cœlenteron is a simple cavity whose walls are relatively smooth and never thrown into folds or ridges. These polyps are frequently very delicately colored and live singly

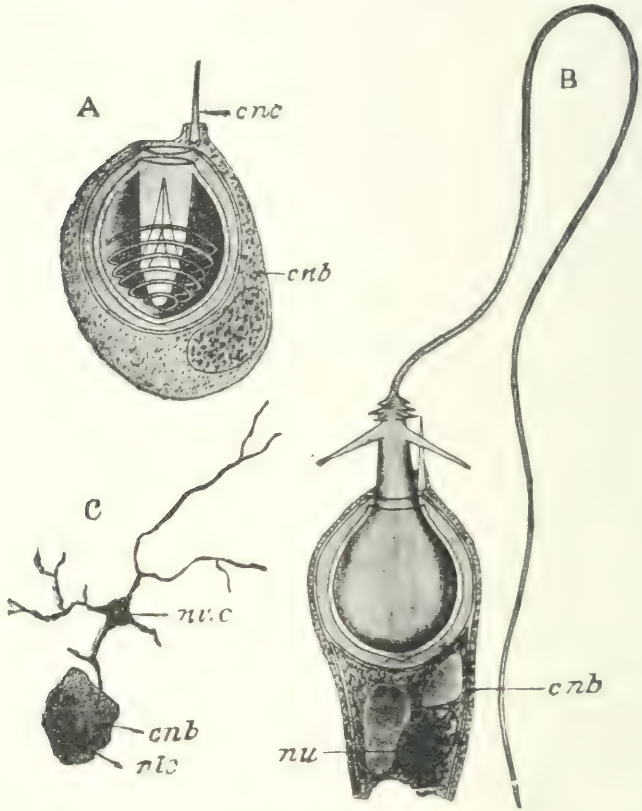



FIG. 45. Nematocysts of *Hydra*. A, undischarged; B, discharged; C, nerve supply. *cnb*, cnidoblast; *cnc*, cnidocil; *nu*, nucleus; *ntc*, nematocyst; *nv.c*, nerve-cells. (After Schneider, from Parker and Haswell's Manual.)

or in colonies (Fig. 47). The latter are often large and very beautifully branched so that they look much like plants. All the polyps in a colony are connected with one another by layers of cells, called the cœnosarc; sometimes the colonies are not branched, but the polyps arise side by side from the cœnosarc, which extends over a considerable area (Fig. 47). These colo-

nies generally have a skeleton, which is usually chitinous, more rarely of calcium carbonate; in either case it is secreted by the ectodermal cells.

The medusæ are generally free-swimming animals, for the

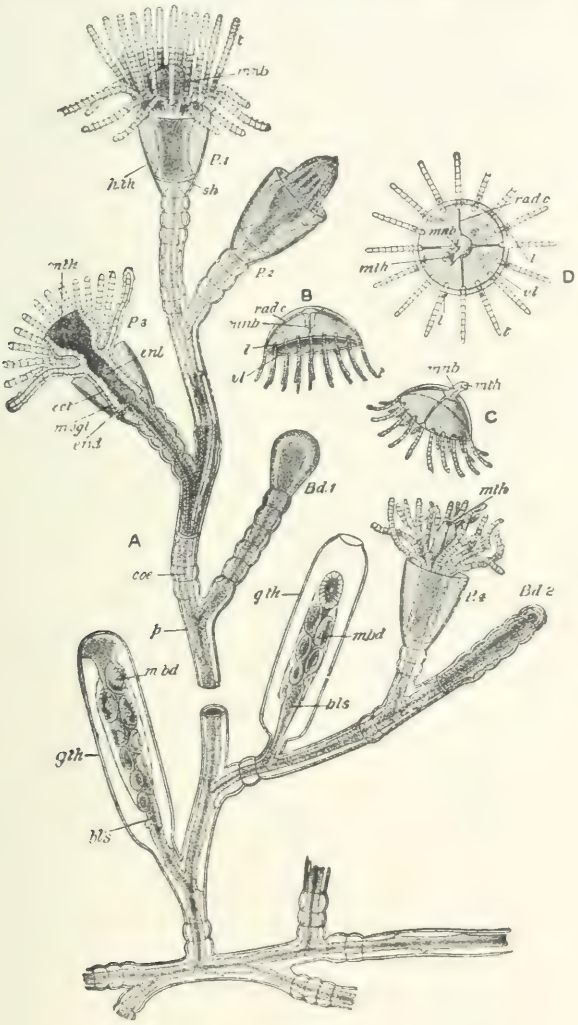



FIG. 46. *Obelia sp.* A, portion of a colony, certain parts in longitudinal section; B, medusa; C, medusa with reversed umbrella; D, oral aspect of medusa. *Bd. 1, 2*, polyp-buds; *bls*, blastostyle; *coe*, cœnosarc; *ect*, ectoderm; *end*, entoderm; *cnt*, cœlenteron; *g.th*, gonotheca; *h.th*, hydrotheca; *l*, lithocyst or octocyst; *m.bd*, medusa-bud; *mnb*, manubrium; *mesgl*, mesoglœa; *mth*, mouth; *p*, perisarc; *P.* 1, 2, 3, 4, polyps; *rad c*, radial canal; *t*, tentacle; *vl*, velum. (After Parker and Haswell.)

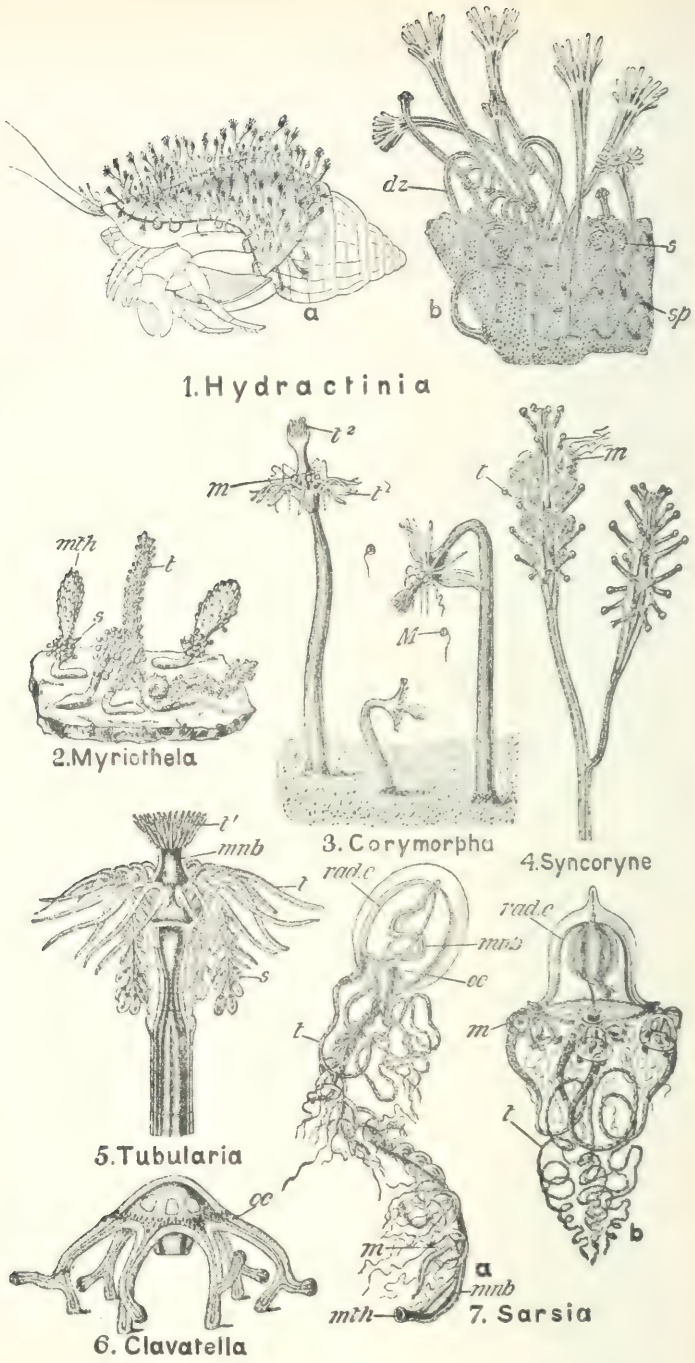



FIG. 47. Various **Hydromedusæ**. 1a, entire colony of hydroids, life-size, on the shell of a hermit-crab; 1b, portion of the same enlarged; 7a, shows medusæ produced by budding from the manubrium; 7b, from the bases of the tentacles. *dz*, dactylozoöids; *m* and *M*, medusæ; *mnb*, manubrium; *mth*, mouth; *oc*, eye-spots; *rad.c*, radial canals; *s*, sporosacs; *sp*, spines; *t*, $t^1$, $t^2$, tentacles. (After Parker and Haswell.)

most part colorless, and constitute what are commonly called the small jellyfishes (Fig. 48). They are more or less bell shaped, so that we speak of the convex surface as the exumbrella, and the concave as the subumbrella. The margin of the bell is smooth and has attached to it tentacles, and also a delicate membrane, which extends inward like a circular shelf around the inner edge; this is known as the velum, or craspedon. Organs of sight and hearing, known respectively as eyes and otocysts, are also found, freely exposed, at the margin of the bell. Suspended in the centre of the subumbrella is an elongated structure, the manubrium, at whose free end is the mouth. The mouth leads into the cœlenteron, which consists of the cavity of the manubrium opening into a central cavity, from which four radial canals pass to the margin of the bell, where they connect with a circular canal. In some cases there are more than four radial canals. The cœlenteron is lined throughout with entoderm, the exterior of the animal is covered with ectoderm, and between the two is a basement membrane, or a mesenchyme. The germ-cells develop from ectodermal cells lying on the radial canals in the subumbrella. There is often an alternation of generations between the polyps and the medusæ, polyps giving rise to medusæ and *vice versa*, and in some cases free-swimming colonies are produced, which consist of both kinds of individuals.

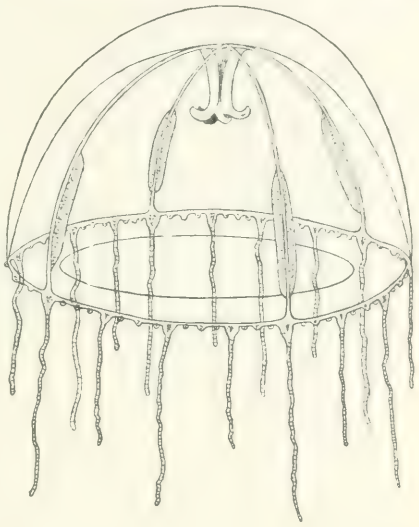


FIG. 48. *Oceania languida*, a craspedote medusa, highly magnified. (Drawn from life by the author.)

### Order 1. Hydridæ

The Hydridæ (Gr. ὕδρα, hydra) constitute a very small order of fresh-water polyps, some brown and some green. They have

a single row of tentacles, which are often very long, and they live singly, not forming colonies. As they reproduce chiefly by budding, temporary colonies are sometimes found, but the young individuals eventually separate from the parent and attach themselves to some foreign object (Fig. 49). Sexual reproduction

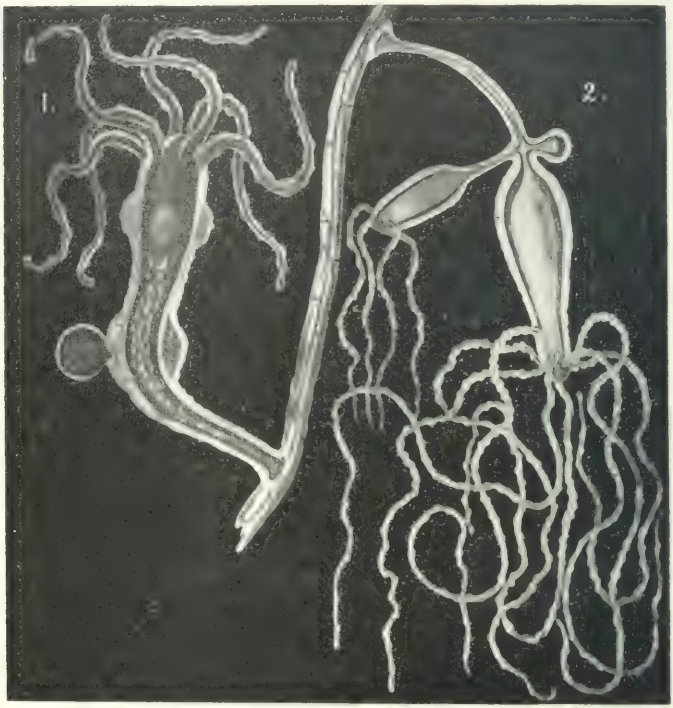



FIG. 49. 1. *Hydra viridis*, the green hydra as it appears in autumn with germ-glands. Below the ring of tentacles appear three testes containing spermatozoa; nearer the attached end is the egg-zone, showing two ova in different stages of development. 2. *Hydra vulgaris*, the brown hydra as it appears in spring — buds developing in place of sexual organs, which form in the autumn. (Photographed from a Leuckart-Nitsche wall-chart, by the author; permission of Dr. C. Chun.)

also occurs, and the ova and spermatozoa are formed from ectodermal cells, both on the same individual, which is therefore hermaphroditic. This group is represented by the genus Hydra, from which the order takes its name.

### Order 2. Hydromedusæ

The Hydromedusæ (Gr. ὕδωρ, water, and Μέδουσα, Medusa) are marine Hydrozoa and include both polyps and medusæ. The polyps are known as hydroids and resemble Hydra described above except in two respects — the hydroids generally form permanent colonies, and they do not themselves produce germ-cells. The colonies are formed by budding, and the cœlenteron of each individual is continuous through the cœnosarc with that of the others (Fig. 46).

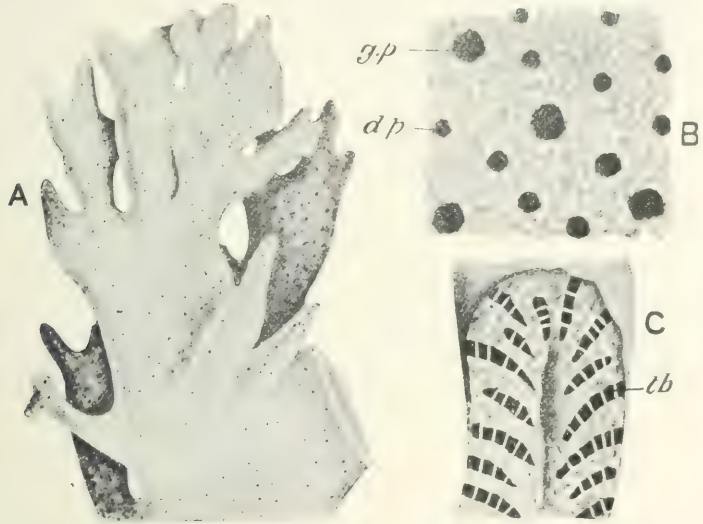



FIG. 50. *Millipora alcicornis*. A, part of skeleton, natural size; B, portion of surface magnified; C, vertical section, magnified. *d.p*, dactylopores; *g.p*, gastropores; *tb*, tabulæ. (After Nicholson and Lydekker, from Parker and Haswell's Text-book.)

Here and there on the colonies budlike outgrowths occur, which do not develop into polyps, but into medusæ, which ultimately separate from the hydroid, and swim about as free-living individuals. These medusæ produce germ-cells from which in turn polyps develop, and thus an alternation of generations is established. While we may call this process typical for the Hydromedusæ, it is by no means constant. For in some hydroids the buds which we might expect to form medusæ never attain a complete development, but remain attached and there produce germ-cells, which escape and develop into new

hydroids; buds of this kind are called gonophores (Fig. 47, 1 *b*, 2, and 5). Furthermore, in some medusæ the fertilized ova do not produce hydroids, but develop directly into medusæ, and in some cases new medusæ are even formed as buds on the manubrium of the parent (Fig. 47, 7). The hydroids often have a cuticular shell or skeleton with openings through which the polyps may be protruded, and in a few genera there is a skeleton of calcium carbonate, thus forming a kind of coral (Fig. 50).

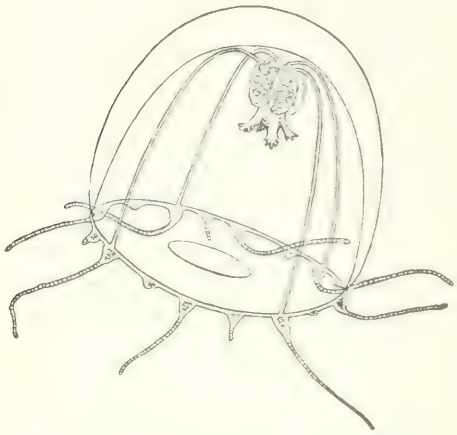


FIG. 51. *Turritopsis nutricula*, a craspedote medusa, highly magnified. (Drawn from life by the author.)

Hydroids occur widely distributed on rocky shores, and are also found in water of one hundred meters or more. Some live on the shells inhabited by hermit-crabs, and in this way are carried about, while their presence conceals and thus protects the crab (Fig. 47, 1 *a*). A similar phenomenon has been referred to under the sponges. The medusæ of this order are pelagic, *i.e.* they swim near the surface of the ocean. They are for the most part small, only a few millimeters in diameter, though a few attain a diameter of several centimeters (Figs. 48, 51, and 52).

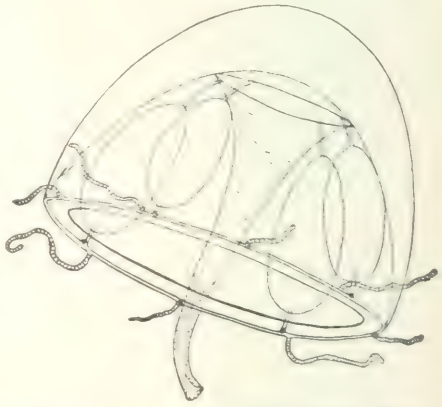


FIG. 52. *Liriope*, a craspedote medusa, highly magnified. (Drawn from life by the author.)

## Order 3. Siphonophora

The Siphonophora (Gr. σιφων, a siphon, and φέρω, to bear) are free-swimming colonies of marine Hydrozoa. These colonies are extremely complicated in structure, owing to the fact that there is great division of labor among the different members composing it, and therefore a difference in form corresponding to the difference in function. The colonies appear to develop from a medusa-like individual, which produces a large number of buds, either on the subumbrella (Fig. 53), or on the greatly elongated manubrium (Fig. 54). As many as seven different kinds of individuals may be found, but all do not generally occur in one colony (Fig. 55). There is often a float, a modified medusa containing a cavity filled with gas, which keeps the colony afloat. Below this there may be a greater or less number of swimming bells, medusæ whose only function is the propulsion of the colony. At various points there may be expanded, leaflike individuals, which serve as a protective covering to those beneath them. Other individuals have very much the appearance of polyps without tentacles, and function as feeding organs. Near them are generally others resembling long tentacles, which

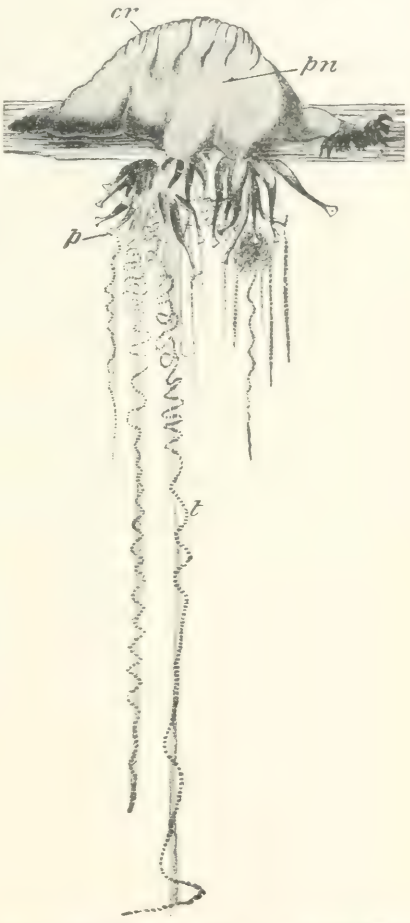



FIG. 53. *Physalia*. As it floats on the surface of the sea. *cr*, crest; *p*, polyp; *pn*, pneumatophore or float. (After Huxley, from Parker and Haswell's Manual.)

FIG. 54. *Halistemma tergestinum*. A, entire colony; B, a single group of zoöids. *cœ*, cœnosarc; *dz*, dactylozooid; *hph*, hydrophyllium or bract; *nct*, nectocalyx or swimming bell; *ntc*, battery of nematocysts; *p*, polyp; *pn*, pneumatophore or float; *s.s'*, spermaries; *t* tentacle. (After Claus, from Parker and Haswell's Textbook.)

possess a very large number of nettle cells; these are clearly defensive. Some resemble polyps without tentacles and without a mouth,—they are supposed to be merely sensory. And finally, some individuals serve entirely for reproduction, producing the germ cells which give rise to new colonies. The Siphonophora are very beautiful, being transparent, with brightly colored spots here and there, and while some are small, others attain a great length. They are particularly abundant in tropical waters, floating on the surface of the ocean. The Portuguese man-of-war, already mentioned (Fig. 53), is a member of this order.

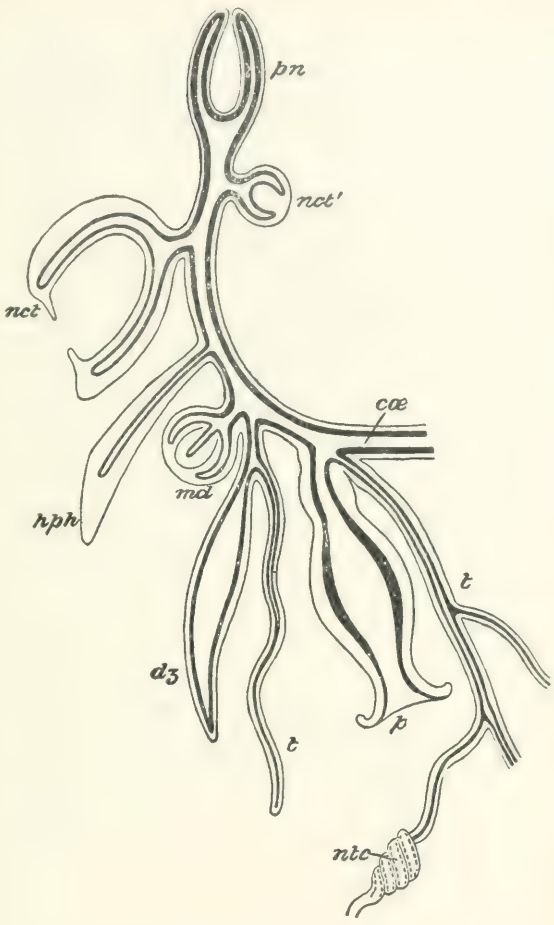



FIG. 55. Diagram of a siphonophore; the thick line represents the entoderm, outside of which is the ectoderm, and the cavity within is the cœlenteron. *cœ*, cœnosarc; *dz*, dactylozooid; *hph*, hydrophyllium; *nct*, *nct'*, nectocalyces; *ntc*, battery of nematocysts; *p*, polyp; *pn*, pneumatophore; *t*, tentacle. (After Claus, from Parker and Haswell's Text-book.)

## CLASS II. SCYPHOZOA

The Scyphozoa (Gr. *σκύφος*, a cup, and *ζῶον*, animal) are all marine and include both polyps and medusæ, but these are very

different in many respects from the polyps and medusæ of the Hydrozoa. Inasmuch as it is necessary to divide this class into two subclasses, one consisting entirely of polyps, and the other, in the adult condition, exclusively of medusæ, it will be simpler to consider the structure of the polyps and the medusæ under their respective subclasses.

## SUBCLASS I. ANTHOZOA

The Anthozoa (Gr. *ἄνθος*, a flower, and *ζῷον*, animal), sometimes called the Actinozoa (Gr. *ἀκτίς*, ray, and *ζῷον*, animal), consist of polyps only, and include those animals which are known popularly as corals and sea anemones. They differ from the hydrozoan polyps in two important points; first, the mouth does not open directly into the cœlenteron, but into a tubular gullet or œsophagus, lined with ectoderm, and the ectoderm and entoderm meet at the inner end of this tube; second, the cœlenteron is not bounded by a smooth wall, but has a number of longitudinal folds projecting into it from the wall; these folds are called mesenteries (Figs. 56, 57, and 58). Another difference, of less fundamental importance, is the fact that, instead of a basement membrane, a mesenchyme is present, containing cells in great abundance. The mouth, which is somewhat elongated instead of circular as in the Hydrozoa, lies in the center of a disc, which has at its margin from one to several rows of tentacles.

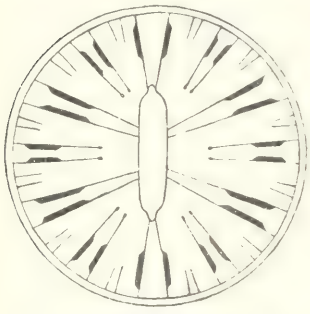


FIG. 56. Diagrammatic cross-section through the œsophageal region of a sea anemone. The coming cavity in the center is the œsophagus. The six pairs of primary mesenteries meet the wall of the œsophagus. The six pairs of secondaries are shorter; the twelve pairs of tertiaries are the shortest of all. In some cases a fourth series may develop, twenty-four pairs, occupying the spaces on each side of each pair of tertiaries. (Drawn by the author.)

The œsophagus is held in position in the cœlenteron by means of some of the mesenteries, which extend from the body wall to it, and are pierced by a circular opening near the mouth, or oral, end of the œsophagus, so that the spaces between the mesenteries are all in communication with each other. The free

edge of the mesenteries, beyond the inner end of the œsophagus, often possesses a greatly twisted thickening, the mesenteric filament, which is very rich in nettle cells and gland cells. In some species there occur, on the edge of the mesentery near the attached end of the animal, long white threads, the acontia, which contain numerous nettle cells, and may be protruded from the mouth or through minute pores in the body wall. These may readily be seen in many sea anemones that have been

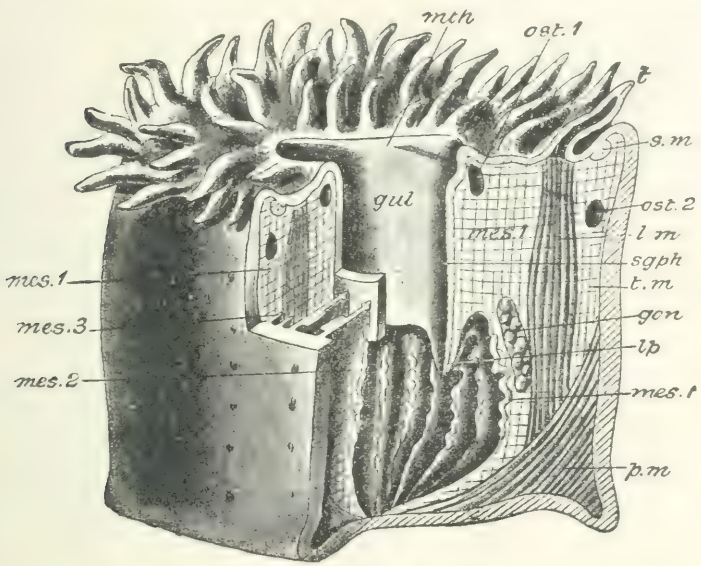



FIG. 57. *Tealia crassicornis.* Dissected. *gon*, gonads; *gul*, gullet; *l.m*, longitudinal muscle; *lp*, lappet; *mes. 1*, *mes. 2*, *mes. 3*, primary, secondary, and tertiary mesenteries; *mes. f*, mesenteric filaments; *mth*, mouth; *ost. 1*, *ost. 2*, ostia or openings in mesenteries; *p.m*, parietal muscle; *sgph*, siphonoglyph; *s.m*, sphincter muscle; *t.m*, transverse muscle. (After Parker and Haswell.)

somewhat roughly handled. Each mesentery is provided with a strong, longitudinal muscle band, which is attached to one side of it, and there is also near the margin a group of germ-cells which arise from the entoderm; the sexes are separate as a rule.

In all the Metazoa that we have considered thus far, wher ever there has been a symmetrical arrangement of the parts of the body, it has been a radical symmetry, *i.e.* the parts have been arranged radially about a central axis. This is true of the Scyphozoa as well, but the elongated mouth on the polyps

and the position of the muscles on only one side of the mesenteries make it possible to pass a plane through the body so as to divide it into two equal parts, thus producing a bilateral symmetry (Fig. 56). In these colonies the individuals are all united by a cœnosarc as in the hydroid colonies. Some Anthozoa have no skeleton, but the majority produce a supporting structure, which consists of calcium carbonate or in some cases of a substance resembling but not identical with horn; at times both kinds occur in one species. The skeleton is usually a compact, solid structure, but in some cases it consists of loosely arranged spicules. It is usually a secretion of the ectoderm, though in some cases it may be formed by the mesenchyme cells, and both kinds of cells take part in secreting the skeleton in some species. Some of the polyps of this class live singly, but by far the greater number form colonies, by budding, often very large and of various shapes, such as cup-shaped, dome-shaped, and branching (Figs. 59 and 60). Reproduction also takes place by means of fertilized eggs, which give rise to ciliated, free-swimming larvae. The larva eventually settles down and develops into a polyp, which lives by itself or produces a colony by budding, as the case may be.

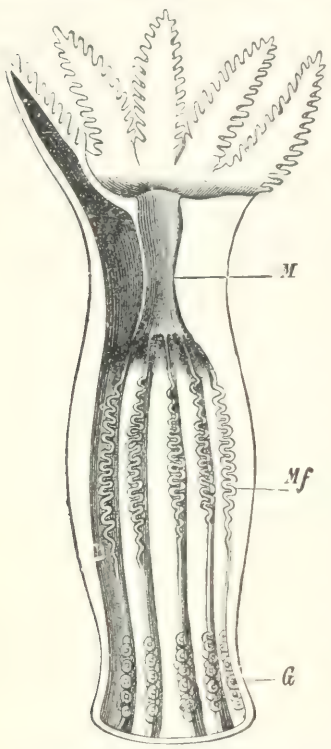



FIG. 58. Longitudinal section through an anthozoan polyp. *G*, germ-glands; *M*, œsophagus; *Mf*, mesenteric folds. Enlarged. (After Claus.)

Many of the Anthozoa are very brilliantly colored. The great variety exhibited by the sea anemones is familiar to all who live by the sea shore; but the living corals are even more beautiful, and are less known to the inhabitants of the temperate zone, for they live for the most part in tropical waters, and one gains no conception of the living animal by seeing the skeleton only.

They exhibit many tints and shades of red, yellow, brown, green, and purple, and often there is a brilliant contrast in color between the polyps and the cœnosarc, as in the red coral, whose polyps are a pure white, while the cœnosarc is crimson. Some corals are a bright blue, others a delicate pink, some a transparent white.

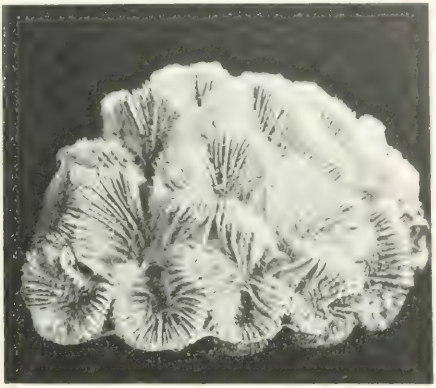


FIG. 59. *Meandrina*, a rose-coral; skeleton, reduced about one half. (Photographed from specimen by the author.)

The sea anemones live for the most part along the shore in shallow water. They are larger than the hydroid polyps and vary greatly in size, some in the tropics attaining a diameter of over sixty centimeters, or about two feet. In some cases there is a kind of symbiosis between sea anemones and other

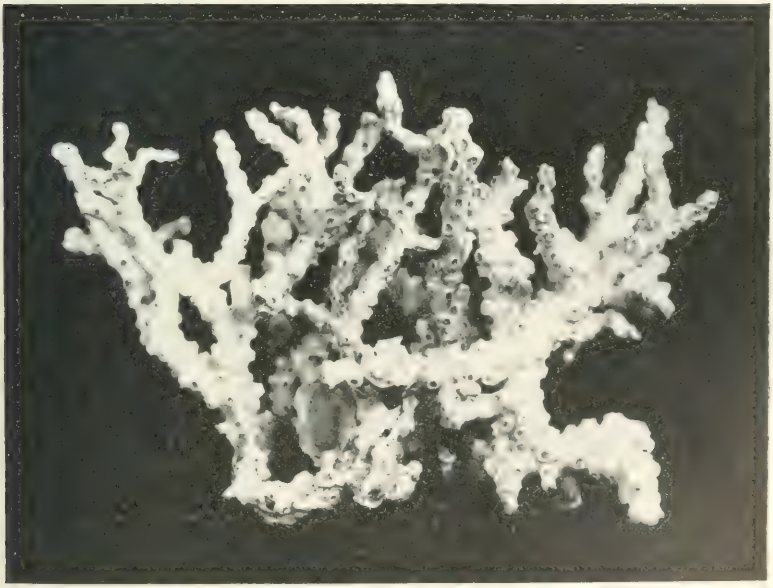


FIG. 60. *Oculina*, a freely branching coral; small fragment of skeleton, slightly reduced. (Photographed from specimen by the author.)

animals, and one of these is strikingly like that mentioned in connection with the hydroid polyps. Here a species of sea anemone becomes attached to the shell in which a hermit crab lives (Fig. 61), and thus gets the benefit of being carried about from place to place, and at the same time serves to conceal the crab from its enemies. The corals, which, as we have said,

FIG. 61. *Adamsia palliata*, four individuals attached to a gastropod shell inhabited by a hermit crab. *ac*, *ac'*, acontia; *sh*, portion of gastropod shell. (After Andres, from Parker and Haswell's Text-book.)

are almost exclusively tropical, never grow in water over eighty meters deep, and many species grow in much shallower water. The red coral lives in the Mediterranean only, and is found in water from twenty to sixty meters deep. The skeletons of corals play a very important part in the formation of many tropical islands and of reefs which break the force of the

waves against the shore. They are also very important geologically and constitute the extensive formations known as the coral limestones.

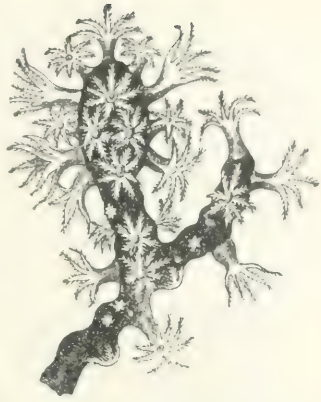


FIG. 62. *Corallium rubrum*. Portion of a colony, enlarged two diameters. (After Lacaze-Duthiers, from Parker and Haswell's Manual.)

### Order 1. Octocorallia

The Octocorallia (Gr. *ὀκτώ*, eight, and *κοράλλιον*, coral), sometimes called the Alcyonaria (Lat. *alcyonium*, sea foam), include many of the animals commonly known as corals, as well as some others. They all possess eight mesenteries, and eight tentacles; the latter are pinnate or feathery in appearance. The valuable red coral (Fig. 62) belongs to this group, as well as the organ-pipe coral (Fig. 63), the sea fans (Fig. 64), and the beautiful sea pens (Fig. 65).

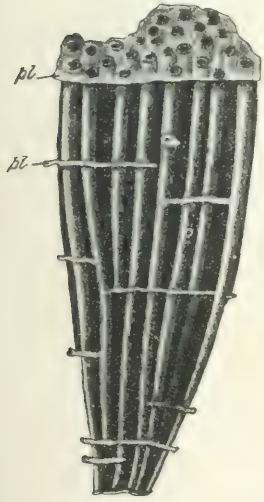



FIG. 63. *Tubipora musica*. Natural size; from the Indian Ocean. *pl*, platform. (After Cuvier, from Parker and Haswell's Manual.)

### Order 2. Hexacorallia

The Hexacorallia (Gr. *ἕξ*, six, and *κοράλλιον*, coral), also known as the Zonatharia (Gr. *ζῷον*, animal, and *ἄνθος*, a flower), consist of the sea anemones (Figs. 61 and 66), and some of the corals. Their mesenteries are usually some multiple of six, and are arranged for the most part in pairs, with the longitudinal muscle bands facing one another. The tentacles are generally simple, hollow tubes, unbranched. The sea anemones have no skeleton, but the so-called stony corals (Figs. 59 and 60) belong for the most part to this order, and have a calcareous skeleton; the black corals secrete a supporting substance resembling horn.

## SUBCLASS II. SCYPHOMEDUSÆ

The Scyphomedusæ (Gr. *σκύφος*, a cup, and *Μέδουσα*, Medusa) are known popularly as the large jellyfishes. There are several points in which they differ from the Hydromedusæ, of which the most important, perhaps, is the absence of a true velum. Further, the margin of the bell is not smooth, but generally lobed more or less deeply, and the sense organs, eyes, and otocysts, which here are modified tentacles, are usually pro-

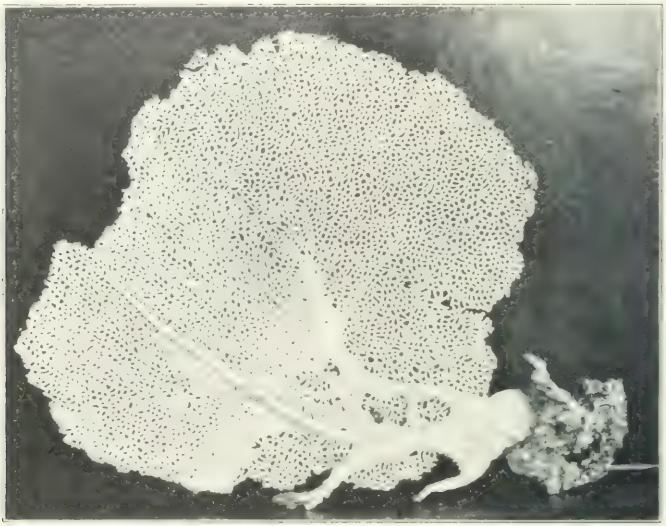


FIG. 64. A sea fan, greatly reduced. (Photographed from specimen by the author.)

tected by a fold which projects over them from the margin of the bell. A greater or less number of tentacles may be present at the margin, and very frequently the manubrium bears four tentacles, which are often long and greatly branched (Fig. 67). Alternating with these four tentacles, there are, on the subumbrella, four pockets or pouches, known as the subgenital pits, because directly above them, on the four radiating canals of the cœlenteron, lie the germ-glands. The germ-cells develop from the entoderm as in the Anthozoa. Adjoining each germ-gland on its central side in the cœlenteron is a series of threadlike processes, the gastric filaments, which are absent in the Hydromedusæ, and correspond to the mesenteric filaments

of the Anthozoa. The cœlenteron is somewhat complex, owing to the fact that there are often more than four radial canals, and that these generally branch greatly as they approach the margin of the bell.

The sexes are usually separate, and the germ-cells are set free into the cœlenteron, and pass out through the mouth. The fertilized ova may develop directly into new medusæ, but in some cases there is a suggestion of an alteration of generations, for the ovum gives rise to a polyp (Fig. 68, E and F) which in general structure resembles the anthozoan polyp. It possesses an œsophagus, and there are four mesenteries in the cœlenteron. This polyp is known as a scyphistoma, and, unlike the hydroid polyp, it does not remain long in this condition so that it must be regarded rather as a larva, for it may develop into a medusa, or by a series of transverse constrictions give rise to a series of young medusæ, called ephyræ (Fig. 68, H and I), attached one above the other, the whole structure being called a strobila (Fig. 68, G). As they mature, each ephyra separates from the rest, and develops into an adult medusa.

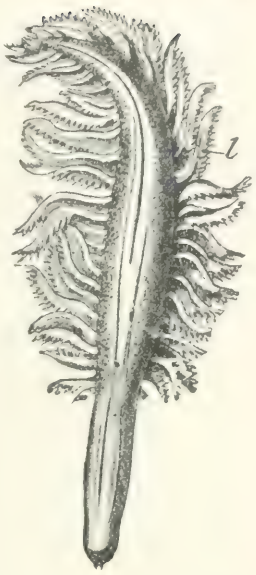



FIG. 65. *Pennatula sulcata.* The sea pen; entire colony. *l*, lateral branch. (After Koelliker, from Parker and Haswell's Manual.)

FIG. 66. A common sea anemone. (After Emerton, from Parker and Haswell's Manual.)

Most of the Scyphomedusæ are free-swimming, pelagic animals, varying greatly in size from a few centimeters to nearly two meters in diameter; and many possess on the exumbrella and tentacles a large number of nettle cells, so that the larger animals can sting unpleasantly. The tentacles are often very

long in proportion to the diameter of the bell; a medusa thirty centimeters in diameter may have tentacles a meter or more in length, while in the largest species they are said to attain a length of forty meters. Both the tentacles and the germ-glands are often very brilliantly and beautifully colored: the rest of the animal is usually nearly colorless, and some are phosphorescent.

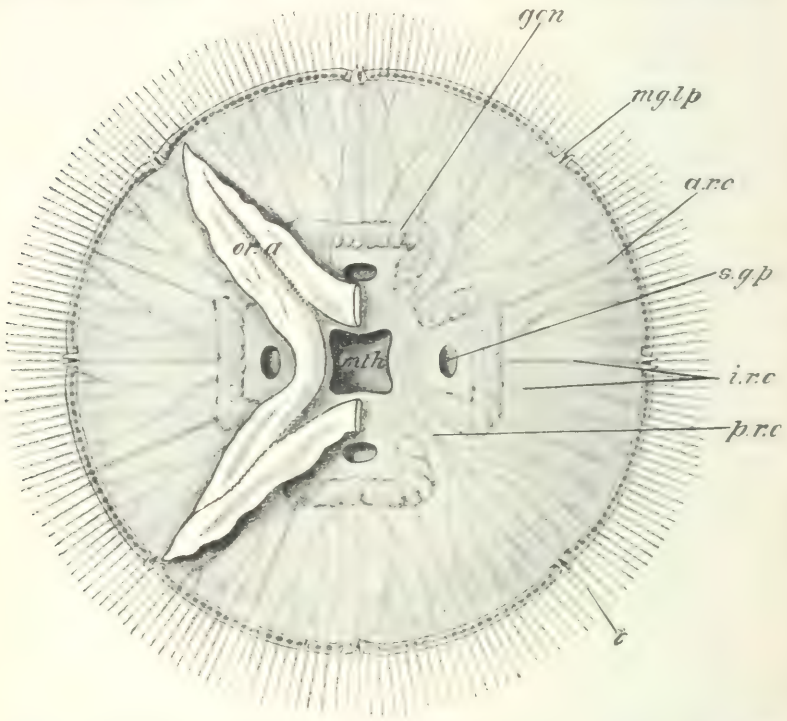



FIG. 67. *Aurelia aurita*. Oral aspect; two of the oral tentacles removed. *a.r.c*, radial canal; *gon*, gonads or germ-glands; *i.r.c*, radial canal; *mg.lp*, marginal lappet; *mth*, mouth; *or.a*, oral arm or tentacle; *p.r.c*, radial canal; *s.g.p*, subgenital pit; *t*, tentacles. (After Parker and Haswell.)

## CLASS III. CTENOPHORA

The Ctenophora (Gr. κτεις, a comb, and φόρος, bearing) are all marine, jellylike animals, and more colorless and transparent than the other Cnidaria. They are sometimes called sea walnuts because of the ovoid shape of the body of some species; but some are bandlike, and others saclike (Figs. 69, 70, and 72). There is a more or less radial arrangement of the parts, but as in the

Anthozoa, there is also bilateral symmetry. The most striking external characteristic consists of eight meridional rows of

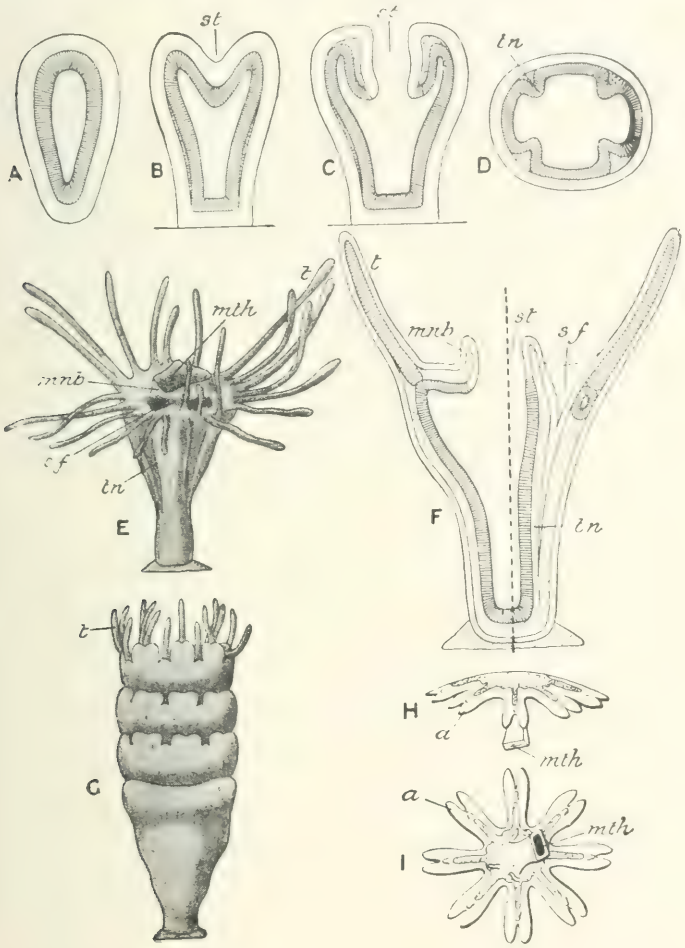



FIG. 68. *Aurelia aurita.* Development. A planula or free-swimming larva; B, C, formation of mouth and œsophagus after attachment; D, transverse section of young scyphistoma; E, scyphistoma; F, longitudinal section of same; G, strobila; H, ephyra, lateral aspect; I, ephyra, oral aspect. In A, B, C, D, F, the ectoderm is unshaded, the entoderm striated, the mesogloea dotted. *a*, lobes of the umbrella; *mnb*, manubrium; *mth*, mouth; *s.f*, septal funnel; *st*, œsophagus; *t*, tentacle; *tn*, tænioles or mesenteries. (From Korschelt and Heider's Embryology.)

vibratile plates, which are made up of fused cilia. These are the organs of locomotion, and it is from them that the class

derives its name. Most of the Ctenophora possess two tentacles which are retractile, and are inserted in pockets on opposite

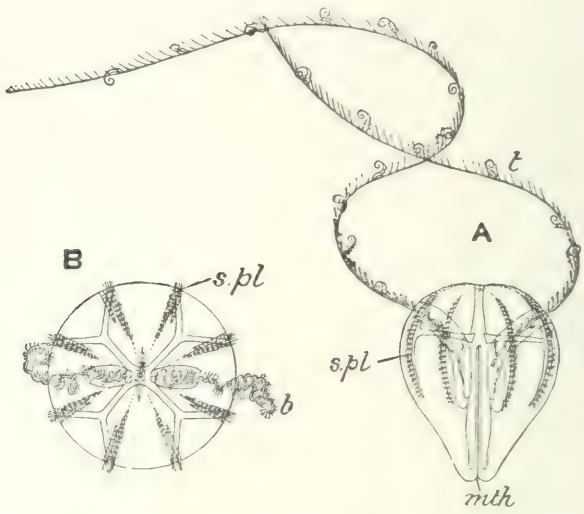



FIG. 69. *Hormiphora* (*Cydippe*) *plumosa*. A, lateral aspect; B, aboral aspect. Natural size; from the Mediterranean Sea. *b*, tentacle; *mth*, mouth; *s.pl*, swimming plates; *t*, tentacle. (After Chun, from Parker and Haswell's Manual.)

sides of the body. The mouth is at one pole of the animal, and at the opposite or aboral pole is a sensory area in the center of which lies an otocyst. Nematocysts are absent in the Ctenophora, but there are cells, the adhesive cells, occurring on the tentacles, which serve essentially the same purpose; they have a hemispherical adhesive surface, and a slender contractile stalk (Fig. 71). The mouth opens into an elongated œsophagus lined with ectoderm, and terminating in the central portion of the cœlenteron, which here consists of several branching tubes, of which the most important terminate in meridional tubes, which lie just beneath the bands of vibratile cilia. On these meridional tubes lie the germ-glands containing on one side of each tube, ova, and on the other, spermatozoa,

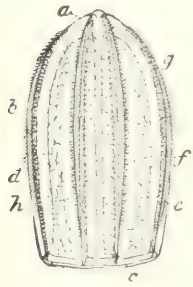



FIG. 70. *Idyia roseola*. Lateral aspect, half natural size. *a*, anal opening; *b*, lateral tube; *c*, circular tube; *d*, *e*, *f*, *g*, *h*, rows of paddles. (After Agassiz, from Parker and Haswell's Manual.)

for all the Ctenophora are hermaphroditic; the germ-cells are set free into the cœlenteron. Entoderm lines the cœlenteron,

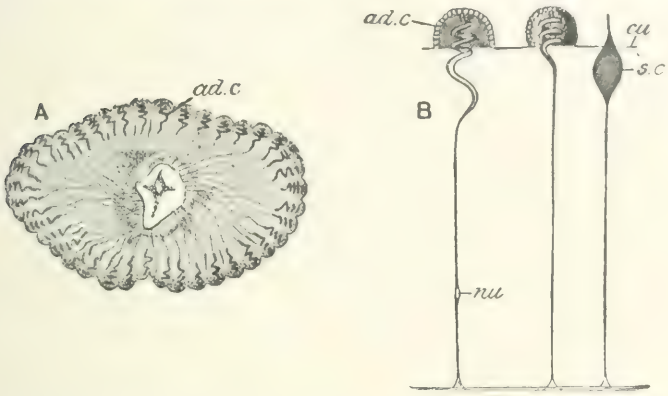



FIG. 71. *Hormiphora plumosa.* A, transverse section of one of the branches of a tentacle; B, two adhesive cells and a sensory cell still more highly magnified. *ad.c*, adhesive cells; *cu*, cuticula; *nu*, nucleus; *s.c*, sensory cell. (After Hertwig and Chun, from Parker and Haswell's Manual.)

and the space between the ectoderm and the entoderm is filled with mesenchyme. There is no alteration of generations in this class, but the young animals often differ from the adult, so that we may speak of them as larvæ. In some species there

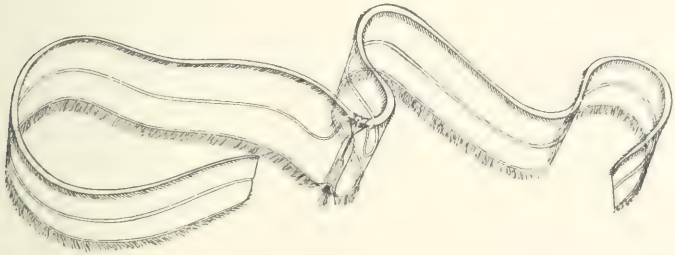


FIG. 72. *Cestus veneris*, the Venus' girdle, showing its undulating form when in motion; the mouth is at the center of the lower edge. (Drawn from a Leuckart-Nitsche wall-chart, by the author; permission of Dr. C. Chun.)

is the curious phenomenon that germ-cells are formed, and mature at two distinct stages in the life of the individual, once when it is young, and again when it is adult.

The Ctenophora are most abundant in tropical waters and are very beautiful, for the moving plates of cilia refract the light and

thus exhibit various brilliant changing colors. Some are excessively fragile. One of the most graceful is the band-shaped Venus' girdle (Fig. 72), which is often about thirty centimeters long and sometimes attains a length of a meter and a half; the young of this species is not band-shaped (Fig. 73).

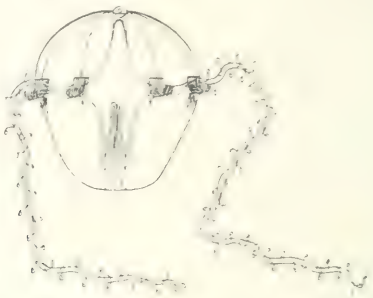


FIG. 73. Larval stage of the Venus' girdle, *Cestus veneris*. (Drawn from a Leuckart-Nitsche wall-chart, by the author; permission of Dr. C. Chun.)

# CHAPTER V

## TYPE III. ECHINODERMATA

The Echinodermata (Gr. ἐχῖνος, hedgehog, sea urchin, and δέρμα, skin) include those animals commonly known as sea lilies or stone lilies, starfishes, brittle or serpent stars, basket fishes, sea urchins, sand dollars, and sea cucumbers. Their position in the system of classification is very doubtful. During the earlier part of the nineteenth century they were placed under one type with the Cœlenterata, and this type was called the Radiata, because the animals composing it exhibited in most cases a radial symmetry. Later, when the anatomy of this group was better known, it became evident that the Echinodermata and the Cœlenterata possessed very few characteristics in common, and the further study of echinoderm embryology has led to the present tendency to place this type much higher in the scale of animal life, in fact only a little below some of the groups closely related to the Vertebrata, or backboned animals. On the other hand, since the position of these animals is still very doubtful, it appears quite as well to take them up at this point as at some other.

The Echinodermata are exclusively marine animals, and, like all the types, exhibit a very great diversity of external form. In general, however, they have a more or less pronounced, superficial, radial symmetry, though in most cases there is bilateral symmetry as well. The parts of the body are usually arranged on a plan of five, so that we can distinguish five radii and the same number of spaces between them, — the interradii; these parts are very apparent in such animals as the starfishes, and are present, though somewhat obscured at times, in all. Along each radius are usually two or more rows of soft tubelike processes, terminating in sucking discs; these are the tube feet or

ambulacral feet, and constitute the chief organ of locomotion. In the skin calcareous spicules are developed, which may unite to form larger or smaller plates, sometimes distinct from one another as in the sea cucumbers, often united to form a tolerably firm skeleton, like that of the common starfishes, of which the parts may be movable upon each other to a certain extent, or perfectly rigid as in the sea urchins.

In their internal structure the Echinodermata are strikingly different from the Cœlenterata. There is no cœlenteron, but, instead, several distinct cavities within the body. The mouth opens into a gastric or digestive cavity which usually terminates in an anus. A well-marked body-cavity, such as has already been described as characteristic of the Metazoa, is present, and this contains the principal organs of the body, such as the digestive system and the reproductive organs. Further, there is a system of blood vessels, constituting the vascular cavity; and finally, a peculiar system of tubes, which is found in no other animal type and known as the water-vascular or ambulacral system, for it is connected with the chief organs of locomotion. This last system merits a more extended description; it consists of several parts (Fig. 74). On the surface of the body, opposite the mouth, *i.e.* the aboral surface, there is generally a skeletal plate situated excentrically in an interradius, pierced by numerous fine holes, a sievelike structure, called the madreporic plate, because of its resemblance in many starfishes to corals of a similar name. This plate connects with a canal which extends from the aboral side of the animal toward the oral, and called the stone canal, because its walls contain par-

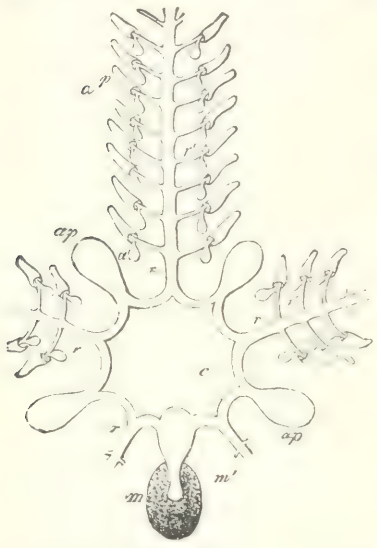



FIG. 74. Ambulacral system of a starfish. *a*, ampullæ; *ap*, Polian vesicles; *c*, circular or ring canal; *m*, madreporic plate or madreporite; *m'*, madreporic or stone canal; *p*, tube feet; *r*, radial canals; *r'*, branches to ampullæ. (After Gegenbaur, from Parker and Haswell's Manual.)

ticles of calcium carbonate. This stone canal connects in turn with a circular canal which runs around the mouth, and possesses on its wall several small sacs, the Polian vesicles. From this circular or ring canal five branches are given off, one of which lies along the median line of each radius, and gives off numerous short, lateral branches, which connect with the tube feet, or ambulacral feet. Each foot terminates within the body in a sacular enlargement, called the ampulla (Fig. 74). The sea water, which has free access to this system of tubes through the madreporic plate, can be forced into the tube feet, which thus become elongated; and, coming in contact with some foreign body, they attach themselves to it by their suckerlike ends, and then shorten by the contraction of the muscles in their walls, forcing the water into the ampullæ, while the animal is drawn toward the object to which the foot is attached. In some Echinodermata, the tube feet do not function as organs of locomotion, but are modified into feelers or tentacles.

The sexes are separate in almost all species of this type, but in a few cases the animals are hermaphroditic; even here, however, the individual does not produce ova and spermatozoa at the same time, but while young is exclusively of one sex, either male or female, and as it grows older becomes exclusively of the opposite sex. There are five classes of living Echinodermata, and two which are exclusively fossil.

## CLASS I. CRINOIDEA

The Crinoidea (Gr. *κρίνον*, lily, and *εἶδος*, form) are known popularly as the sea lilies or the stone lilies, or sometimes as the feather stars. These animals were once very abundant, for we find nearly four times as many fossil species as there are species living to-day, and their remains extend as far back as the Cambrian. They live almost exclusively in deep water, so that they can be obtained only by dredging. Almost all are provided with a stalk, consisting of calcareous plates, piled one upon the other (Fig. 75). This stalk is not very long, — in some cases it may be half a meter or more in length, but among the fossils it has been found from eighteen to twenty meters long. In one group of living Crinoidea there is no stalk in the adult

animal (Fig. 76), which can thus move about from place to place, but even here a stalk is present in the larva. At the free end of the stalk is the cup or calyx, provided with the oral disc on its upper surface, the mouth being near the center, and on the same surface is the anus, excentrically placed. Surrounding this disc are the arms, which at their point of origin are five in number, radially arranged, and as they usually branch dichotomously, there are many more at the tips. The arms are supported by skeletal plates arranged end to end, and from each plate a short lateral branch is given off; these lateral branches are called pinnulæ, — they suggest the barbs on a feather. At the mouth five grooves arise, which pass radially across the oral disc and along the oral surface of each arm, dividing as the arms divide; these are the ambulacral grooves, and they are provided with hollow tentacles which are a part of the water vascular system, and thus correspond to the tube feet.

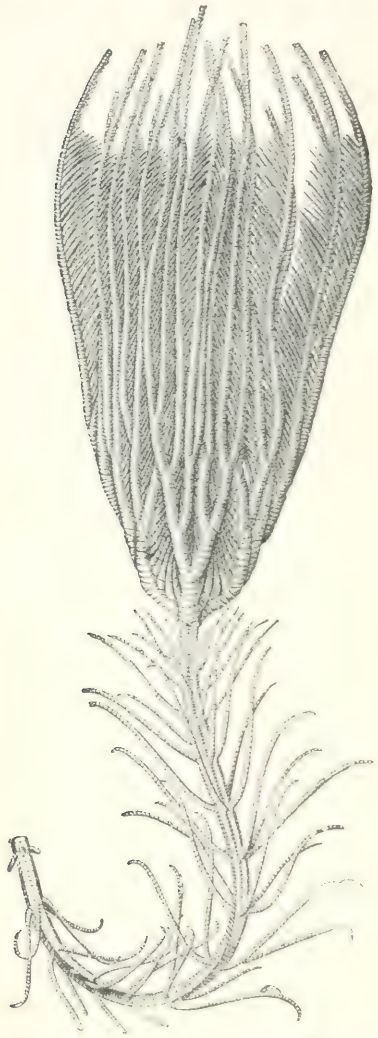


FIG. 75. *Metacrinus interscapus*. A stalked crinoid. (After Carpenter, from Parker and Haswell's Manual.)

The Crinoidea are often attractively colored, occurring in white, purple, yellow, and brown. Of their development we know but little. The sexes are separate, and in those species whose development has been observed a bilaterally symmetrical larva, more or less ciliated, is produced. This class possesses

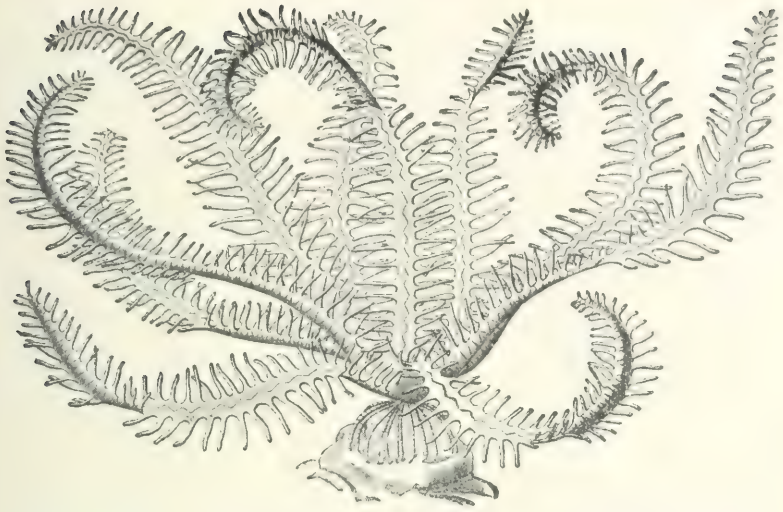


FIG. 76. *Antedon*. An unattached crinoid of Europe, lateral aspect. (From Parker and Haswell's Manual.)

to a considerable degree the power of regenerating lost parts. If the viscera are lost, new viscera develop, and when the arms break off, as they frequently do, new arms are formed in their place.

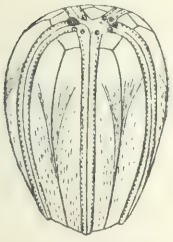


FIG. 77. *Granatocrinus*, one of the Blastoidea; fossil. (Drawn from specimen by the author.)

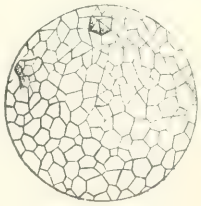


FIG. 78. *Echinosphærites aurantium*, one of the Cystoidea; fossil. (Drawn from specimen by the author.)

There are two classes of Echinodermata, which are closely related to the Crinoidea, but the representatives of these classes are entirely extinct and therefore preserved for us as fossils only. These two classes are the Blastoidea (Fig. 77) and the Cystoidea (Fig. 78); the former appeared in the Upper Silurian and disappeared after the Carboniferous; the latter arose earlier, in the Lower Silurian, to disappear in the Carboniferous.

## CLASS II. ASTEROIDEA

The Asteroidea (Gr. *ἀστήρ*, a star, and *εἶδος*, form) include the common starfishes. These animals are common in the tide pools along the shore and on the bottom below low-water mark,

as well as in the deep sea. Typically they consist of a central disc from which five arms radiate, broad at their region of attachment to the disc, and tapering toward their tips. In some species there is a much larger number of arms. The aboral surface of the animal is usually more or less covered with spines, and with short, soft, tentacle-like processes, which probably assist in respiration. In one interradius on this surface is the madreporic plate already referred to; this is often of a bright orange color, and its position furnishes an opportunity for naming the arms, the two adjoining the plate being called the bivium, the remaining three the trivium. Further, it will be noticed that if a vertical plane be passed through the madreporic plate and the arm opposite it, this plane divides the starfish into two equal, symmetrical parts, and is therefore the plane of bilateral symmetry of the body.

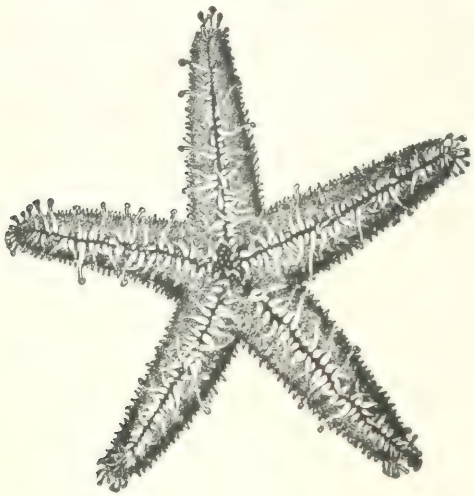


FIG. 79. Oral surface of a common starfish, showing tube feet. (From Parker and Haswell's Manual.)

At the tip of each arm, on its oral side, is a bright red spot, which is a sort of eye, and when the starfish walks about, the tips of the arms are kept turned up, so that these eyes may be of use. Along each arm, on its oral side, is the ambulacral groove, in which are usually either two or four rows of tube feet (Fig. 79). The ambulacral groove is bounded by rows of well-developed spines. The spines of the starfish are frequently surrounded at their bases by minute pincerlike structures, sometimes sessile, sometimes raised on a stalk, and the jaws of the pincers may be straight, or crossed like the blades of a pair of scissors; these organs are called pedicellariæ, and their function is very doubtful.

The mouth of the starfish lies in the center of the disc at the point from which the ambulacral grooves diverge, and opens

into a saclike stomach, the greater part of which can be protruded from the mouth and inserted between the valves of the shells of mussels and similar animals on which the starfish feeds. The deeper part of the stomach sends branches into each arm, and these branches are connected with glandular organs, the hepatic cæca, which assist in digestion. There may or may not be an anus, connecting with the deeper part of the stomach, in the central part of the aboral disc. The arms of the common starfish are hollow, *i.e.* they possess a large body-cavity, which, in addition to the hepatic caeca, contains also the reproductive organs or germ-glands, of which there are two in each arm, and their ducts opening to the outside in the interradii. The ampullæ connected with the inner ends of the tube feet also lie in the body-cavity, and the feet pass out through the openings between the plates of the oral skeleton. The skeleton on the aboral side of the body consists of an irregular network of hard parts; but on the oral side the calcareous plates are arranged along the ambulacral groove like rafters in contact with one another, and are called the ambulacral rafters; there is also more or less regularity in the arrangement of the skeletal plates which connect these rafters with the aboral skeleton.

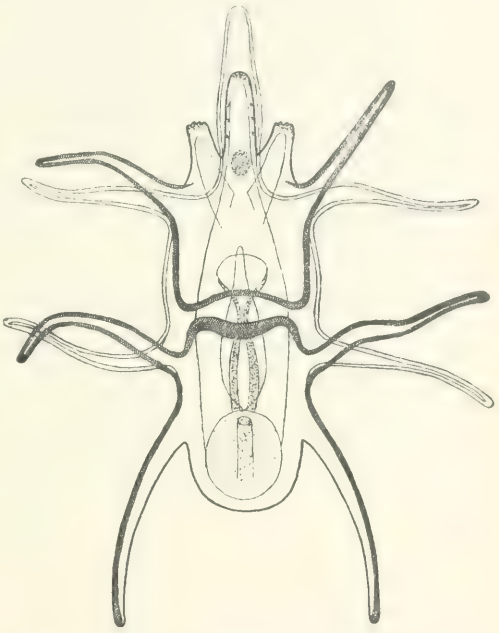


FIG. 80. Brachiolarian larva of the common starfish, *Asterias*, ventral aspect; highly magnified. (Drawn from life by the author.)

The development of the Asteroidea, like that of all the Echinodermata, is pretty complicated. The fertilized egg develops into a bilaterally symmetrical, ciliated larva (Fig. 80).

At first the cilia cover the entire larva, but they early become confined to definite bands. Many arms develop, and finally the starfish begins to form, budding out as it were on one side of the body of the larva (Fig. 81), while the larva itself is gradually absorbed into the growing starfish.

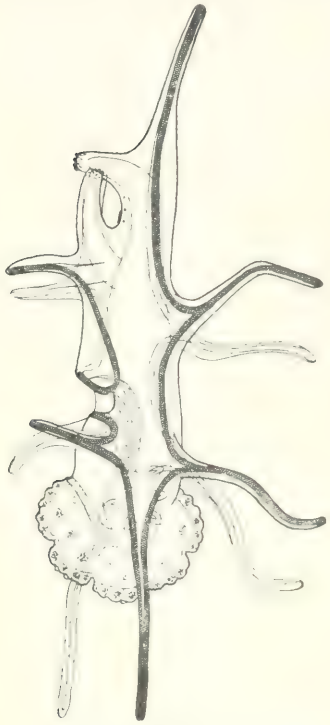


FIG. 81. Brachiolarian larva of the common starfish, *Asterias*, lateral aspect, with young starfish developing at the posterior end; highly magnified. (Drawn from life by the author.)

The common starfishes found in the tide pools along the eastern coast of the United States are usually only from fifteen to twenty centimeters in diameter, while in deeper waters they are sometimes found from twenty-five to thirty centimeters in diameter. But on the Pacific coast there are much larger species, which grow to be from seventy-five centimeters to a meter in diameter. Great variation occurs in the size and distribution of the spines, in the size and number of the arms, and in the extent of the interradial spaces, for these in some cases are almost filled up, so that the animal is pentagonal (Figs. 82 and 83). In some species, too, the chief axis, *i.e.* the axis from the oral to the aboral pole, which is usually short, may be much lengthened in proportion to the diameter of the starfish, which thus appears much swollen. In color there is also much diversity. Some starfishes are a deep purple, others are red, or various shades of yellow, orange, or light brown. The chief economic interest in the starfishes lies in the fact that they feed upon oysters and thus cause much loss to the oystermen. The practice of cutting up the starfishes and throwing them back into the water when they were found clinging to the oysters proved of little value, for the separate pieces might each develop into a complete animal. The starfishes possess this power to a consider-

able degree, and when seized by one arm often separate it from the rest of the body close to the central disc, and thus escape (Fig. 84).

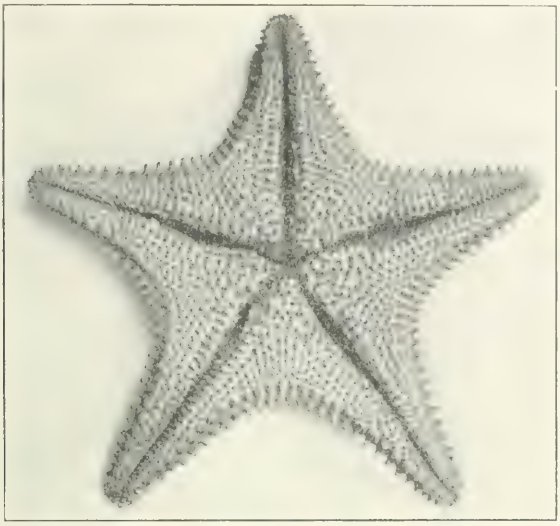


FIG. 82. *Pentaceros reticularis*, oral aspect; common in Florida; the largest starfish on the eastern shore of the United States; attains a diameter of thirty or more centimeters. (Photographed from a dried specimen by the author.)

## CLASS III. OPHIUROIDEA

The Ophiuroidea (Gr. ὄφις, serpent, and εἶδος, form) are the serpent or brittle stars and the basket fishes. The serpent stars resemble the common starfishes in their general shape, but the arms are much more slender, and of very nearly the same diameter throughout their length (Fig. 85), so that the interradial spaces are much broader. The skeletal plates are often regularly arranged on the aboral surface of the central disc, but the madreporic plate lies in an interradius on the oral surface. Here, too, we find in each interradius a pair of slitlike openings, ten in all, which lead into pockets

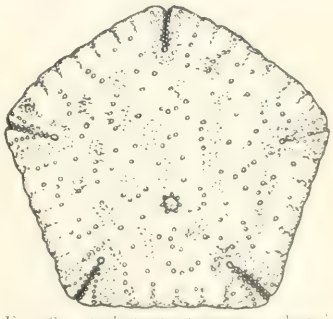


FIG. 83. *Culcita pentagona* Ag., aboral surface; reduced. (From Ludwig-Leunis' Synopsis der Thierkunde.)

or bursæ which extend into the body-cavity. These pockets are connected with the reproductive organs, and frequently serve as brood pouches in which the young undergo a part of their development. The arms of the serpent stars are often transversely banded in light and dark colors on their aboral surface, and this, together with their writhing, serpentine movement, has suggested the common name for these animals. The arms break very readily, thus furnishing the name, brittle stars. Instead of containing a large body-cavity like the arms of the common starfishes, they are nearly solid, owing to the presence of the large calcareous

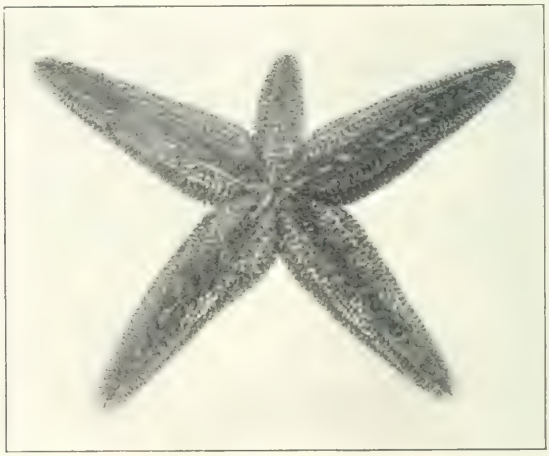


FIG. 84. *Asterias vulgaris*, a common starfish on the northern portion of our Atlantic coast; specimen with regenerating arm, oral aspect, reduced. (Photographed from a dried specimen by the author.)

plates of the skeleton, which occupy the place of the ambulacral grooves in the common stars. On this account the tube feet cannot project from the oral side of the arms, but extend out laterally and take no part in the locomotion of the animal, being reduced to tentacle-like structures, without suckers at their free ends, and without ampullæ at their inner ends. The arms generally bear spines which are situated along their lateral borders. The reproductive organs and the digestive tract lie exclusively in the central disc, and an anus is absent.

The basket fishes differ from the brittle stars chiefly in having the arms branched dichotomously again and again, and these

arms may be coiled up or folded toward the mouth, giving the animal a sort of basketlike appearance (Fig. 86). The skeletal system is much less developed here, and instead the integument is thick; spines are absent.

The development of the Ophiuroidea may be direct, as in those cases where the bursæ function as brood pouches, or

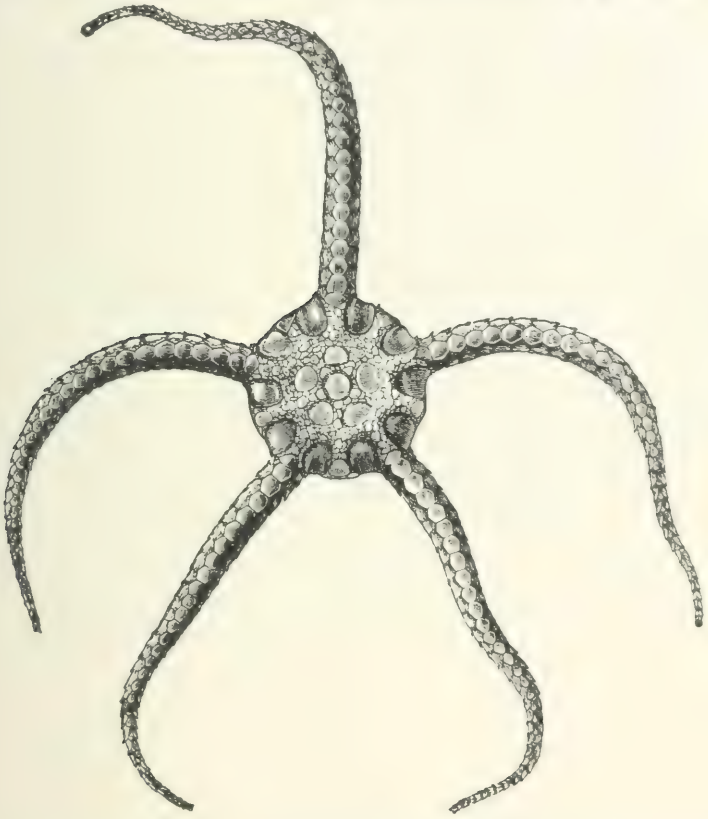


FIG. 85. *Ophioglypha bullata*, a serpent-star, aboral aspect; enlarged about two and a half diameters. (From Shipley and MacBride's Zoölogy.)

there may be a bilaterally symmetrical, free-swimming larva, resembling those found in other groups of the Echinodermata. A few of the representatives of this class live near the shore, but we find them at all depths, even in the deep sea; some live at certain depths only, others exist over a much greater area. A specimen which is thirty centimeters in diameter is considered

large, though some have been found of twice that size. Those occurring in the tide pools are small.

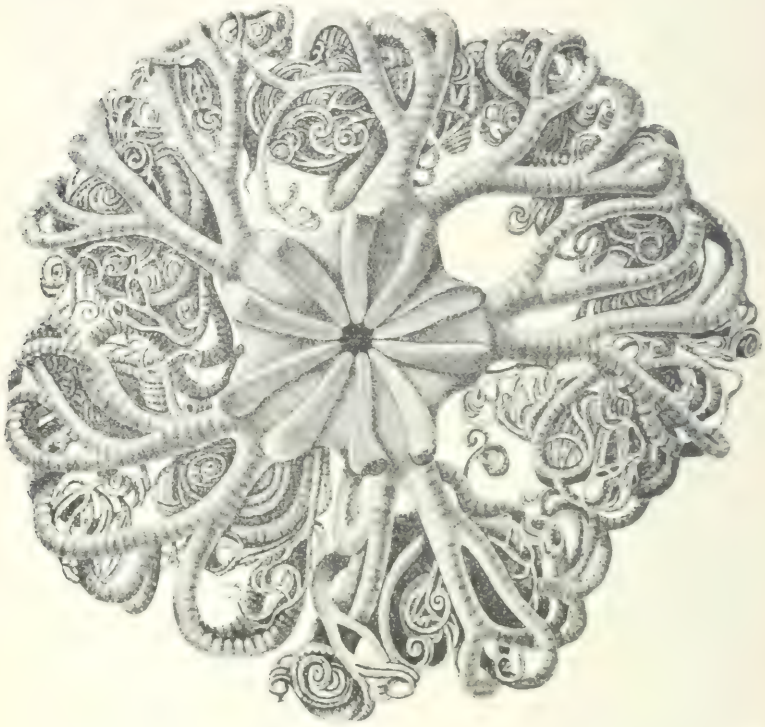


FIG. 86. *Astrophyton arborescens*, basket fish. (After Ludwig, from Parker and Haswell's Text-book.)

## CLASS IV. ECHINOIDEA

The Echinoidea (Gr. ἐχῖνος, sea urchin, and εἶδος, form) include the sea urchins, sand dollars and similar animals. The common sea urchins (Fig. 87) found in the tide pools along the shore are dome-shaped and covered with longer or shorter spines, which are movable to a certain extent. Stalked pedicellariæ are present, similar to those which occur in the starfishes, but they have three or four jaws instead of two. Projecting between the spines on certain parts of the body are tube feet like those in the ambulacral grooves of the starfishes, but usually more extensible. On the oral side of the animal, the spines and the hard shell, or test, beneath them cease at some

distance from the mouth, which is surrounded by a rather firm membrane. From the mouth itself project the tips of five teeth, radially arranged. The anus is at the opposite pole of the animal, and is provided with skeletal plates more or less regularly arranged, around which are two concentric series of

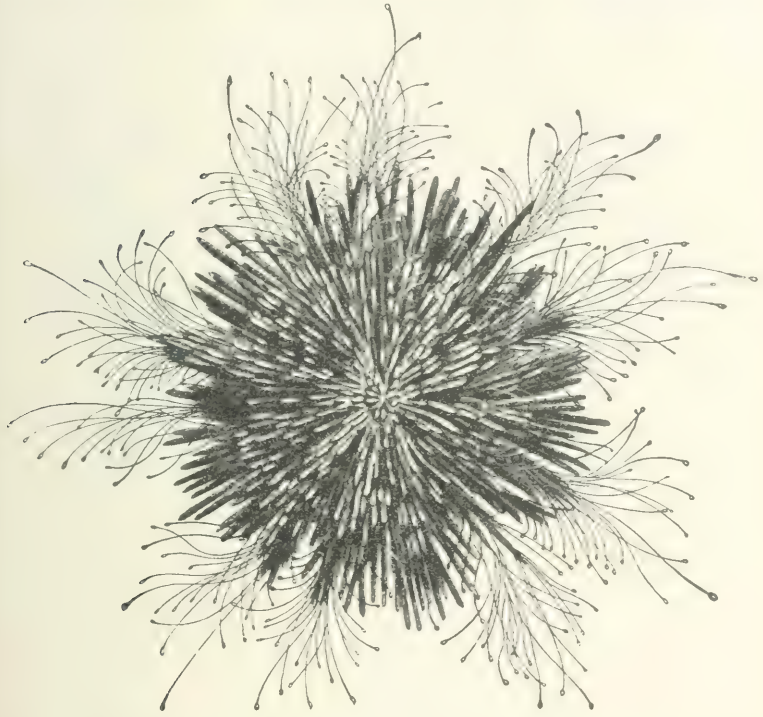


FIG. 87. *Strongylocentrotus*, aboral aspect, showing spines and tube feet. (From Parker and Haswell's Manual.)

regular plates, five in each series. The inner five are called the genital plates, for each is pierced by an opening which marks the orifice of the duct from one of the five germ-glands. One of these plates is pierced by a large number of pores, and this is the madreporic plate, corresponding to the same structure in the starfishes, and communicating with the water vascular system, the structure of which is much the same as the type already described. The outer five plates, which alternate in position with the genital plates, are called ocular plates, for a

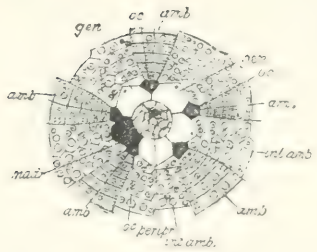



FIG. 88. Arrangement of skeletal plates at the aboral pole of a sea urchin. *amb*, ambulacral zones; *gen*, genital plates; *int. amb*, interambulacral zones; *madr*, madreporic plate; *oc*, ocular plates; *per*, peristomial or anal plates. (After Leuckart, from Parker and Haswell's Manual.)

pigment spot which they may bear has been considered by some zoölogists as an eye (Fig. 88).

The spines of the sea urchin are attached to the shell by means of a ball and socket joint, and are pretty freely movable by means of muscles (Fig. 89). If the spines are removed, the shell is seen to consist of twenty meridional series of plates, firmly united with one another so that they are immovable, and bearing numerous bosses or knoblike projections which are the balls on which the spines rest with their concave ends (Fig. 90). These twenty series of plates form ten double bands, five of which are pierced by numerous small holes through which the tube feet project; these five lie in the same radii as the ocular plates, and the plates of which they are composed are called the ambulacral plates; the five remaining series alternate with these and their plates are called the interambulacral plates, terminating on the aboral side in the genital plates. The chewing apparatus is highly developed in the sea urchins. The five teeth already referred to are firmly fixed in sockets composed of calcareous plates, which are closely united by other plates and by muscles. The whole structure is called Aristotle's lantern (Fig. 91). The mouth opens into an œsophagus, which passes into an elongated intestine, coiled up within the shell, and terminating in the anus.

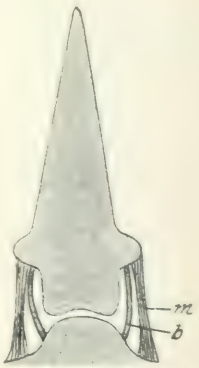



FIG. 89. Diagram of spine of sea urchin, showing method of articulation. *b*, ligament; *m*, muscle. (From Parker and Haswell's Text-book.)

The larva of the sea urchins, known technically as the pluteus larva (Fig. 92), is bilaterally symmetrical as in the other Echinodermata, but its arms are supported by a delicate calcareous skeleton, and therefore more rigid than in the starfish larva. The adult develops in very much the same way

as in the starfishes, the larva being absorbed by the growing sea urchin.

The sand dollars are greatly flattened Echinoidea, covered with very numerous, short, delicate spines. The mouth is centrally

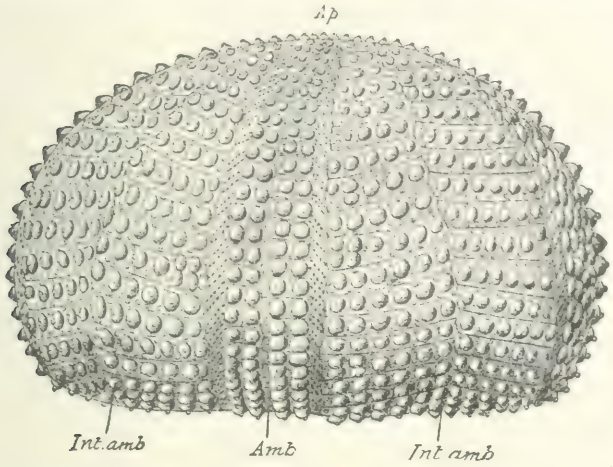



FIG. 90. Shell of sea urchin with spines removed, lateral aspect. *Amb*, ambulacral zone with perforated plates; *Ap*, aboral pole; *Int.amb*, interambulacral zones. (From Parker and Haswell's Manual.)

placed and is provided with five teeth, which are not so highly developed, however, as in the sea urchins; the anus is at the margin of the disc-like body instead of on the aboral surface. The ambulacral feet are not functional in these animals, and are confined to five double, radial bands on the aboral surface; in structure they are tentacle-like, and probably serve a respiratory function merely.

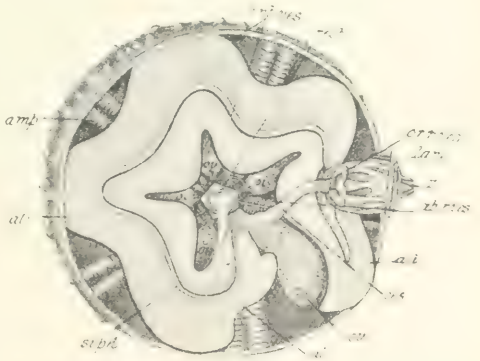



FIG. 91. Sea urchin with oral half of shell removed and mouth parts displaced to one side. *ab.r.ves*, aboral ring vessel of the blood system; *ali*, alimentary canal; *amp*, ampullæ; *int.ves*, intestinal blood vessels; *lant*, Aristotle's lantern; *oes*, œsophagus; *or.r.v*, oral ring vessel of blood system; *ov*, ovary; *rect*, rectum; *siph*, siphon. (Partly after Cuvier, from Parker and Haswell's Text-book.)

The common sea urchins measure only a few centimeters in

diameter, but along the Pacific coast they have been found with a shell some fifteen centimeters broad and spines half as long, so that the animal measured some thirty centimeters. Dr. Alexander Agassiz has described a species which he dredged, in which the shell measured 312 millimeters. There is much variety of color in this group, some species being green, others purple, and some yellowish and pinkish. Those which live in deeper water show much diversity of form; the spines are sometimes very long and greatly thickened, sometimes broad and platelike, and often highly ornamented by flutings and ridges. Some species have curious hollows or pouches, in the shell, partly covered by spines, and these serve as brood pouches, where the young undergo a certain part of their development. Some of these species which have such striking bilateral symmetry exhibit a considerable variation in the positions of the mouth and anus. The mouth no longer occupies the center of the oral surface, but has moved towards what we may call the anterior end, and the anus comes to lie on the oral surface of the animal instead of on the margin or on the aboral side, as in the more distinctly radially symmetrical species. The number of living species of sea urchins is very small compared with the number of fossil species.

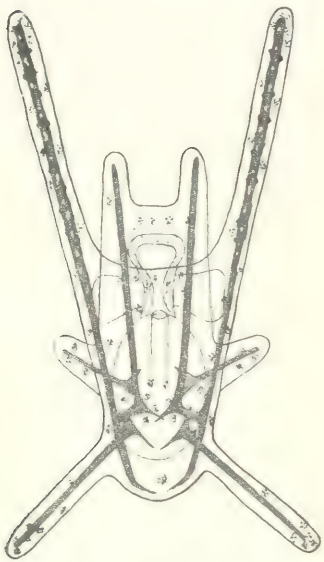


FIG. 92. *Arbacia punctata*, a sea urchin; plutei [illegible] showing larval skeleton; somewhat diagrammatic and highly magnified. (Drawn from life by the author.)

## CLASS V. HOLOTHUROIDEA

The Holothuroidea (Gr. ὅλος, whole, and θυροειδής, like a door) consist of the sea cucumbers. The common name for these animals is very applicable in many cases, for they are often more or less cylindrical, and with little evidence of that radial arrangement of parts which is so characteristic of the other classes.

Many of the Holothuroidea, in fact, resemble the worms much more closely than they resemble the other Echinodermata, for in this type the chief axis of the body, which extends from the oral to the aboral pole, is relatively short as a rule, but in the Holothuroidea it is greatly elongated, the mouth being at one end and the anus at the other. The body wall is almost always soft, more or less leathery, and apparently destitute of a skeleton; but calcareous plates are often present in the skin, and these plates are often elaborate and ornamental structures, taking the form of rosettes, anchors, sieve plates, etc. The mouth is surrounded by a circle of soft tentacles, varying in number from ten to thirty, sometimes short, often long and beautifully branched (Fig. 93). The surface of the body may be perfectly smooth, but generally it is marked by five longitudinal bands, corresponding to the ambulacral areas on other Echinodermata, and the spaces between them to the interambulacral areas (Fig. 93). On these bands there are sometimes ambulacral feet, more often merely tentacles, and in some species there are tentacles attached irregularly over the whole body. The radial symmetry indicated by the ambulacral and interambulacral areas, however, is generally masked by the bilateral symmetry which these animals have acquired by lying habitually on one side, represented by two interambulacral areas and the adjacent three ambulacral areas, which are called the trivium, the remaining two the bivium. Thus the sea cucumbers have as a rule pretty distinct upper and lower surfaces, which are further more or less modified in

FIG. 93. *Cucumaria planci.* Ventral aspect, with tentacles expanded and tube feet extended. (After Ludwig, from Parker and Haswell's Manual.)

several details; the trivium is usually flattened, often the lighter in color, and the ambulacral feet may be confined to that region. A madreporic plate is scarcely ever found on the surface of the

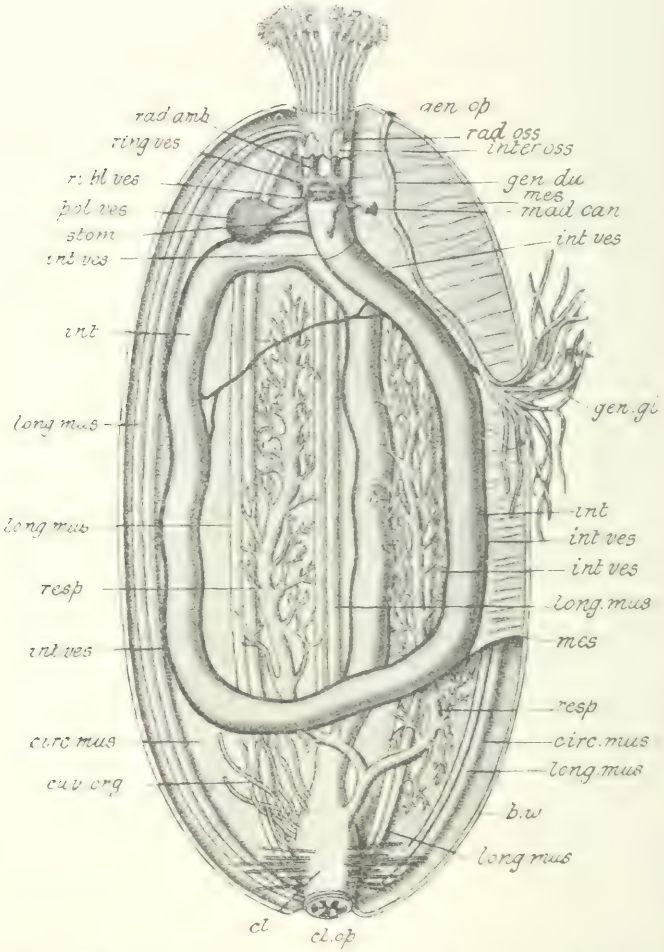



FIG. 94. Internal organs of a [illegible] when the body wall is divided along the middle of the dorsal surface. [illegible] body wall [illegible] circular rows of muscles; *cl*, cloaca; *cl.op*, cloacal opening; *cuv.org*, Cuvierian organs; *gen. du*, genital duct; *gen.gl*, germ-gland; *gen. op*, genital opening; *int*, intestine; *inter.oss*, interambulacral [illegible]; *int.ves*, intestinal vessels; *long.mus*, longitudinal muscle band; *mad.can*, madreporic canals; *mes*, mesentery; *pol.ves*, Polian vesicles; *rad.amb*, radial ambulacral vessels; *ri.bl.ves*, ring blood vessel; *resp*, respiratory trees; *ring.ves*, ring vessel of ambulacral system; *stom*, stomach. (After Leuckart, from Parker and Haswell's Text-book.)

body, though it often occurs at the extremity of the stone canal, which lies freely within the body-cavity.

The alimentary canal is much longer than the chief axis of the body and lies coiled up in the body-cavity, its walls usually having a rich supply of blood vessels. Its posterior end is enlarged, forming a saclike chamber called the cloaca, into which open two greatly branched systems of tubes, which generally extend throughout the whole length of the body-cavity, and are called the respiratory tree because of their supposed function and their treelike appearance (Fig. 94). There is a single germ-gland, which lies in the dorsal interradius, *i.e.* between the two ambulacral areas called the bivium; it consists of a number of tubules, whose common duct passes forward and opens near the base of the circle of circumoral tentacles. The Holothuroidea generally develop by means of bilaterally symmetrical larvæ, which resemble very much the earlier stages of the larvæ of the common starfishes. In some groups no larva occurs, but the young develop directly, being retained close to the external surface of the body of the parent, where they are protected by tentacle-like structures. The inner portion of the body wall is provided with well-developed muscles, arranged in part circularly, passing around the body, and in part as longitudinal bands extending along the ambulacral areas. These muscles assist largely in the locomotion of the animals, especially in those species in which ambulacral feet are wanting; the tentacles sometimes assist in this function also, but one of their chief purposes is to secure food. At times, especially if seized by other animals or roughly handled, the strong contraction of the muscles of the body wall ejects the viscera from the body, and under favorable conditions these may be formed anew, just as the starfish regenerates its lost arms and their contained viscera.

The sea cucumbers vary greatly in color, form, and size. In the temperate regions they are generally not brightly colored, being of various shades of brown or buff, or sometimes nearly transparent; in the tropics there are many species which are a brilliant yellow. They live in the sand and along the shore and at all depths out to the deep sea. In form they range from the simple, cylindrical, wormlike species (Fig. 95) to the elaborate,

strikingly bilateral. In size they vary from minute individuals only a centimeter in length to the gigantic specimens a meter long and twenty centimeters thick which have been found in the Pacific off the Samoan and the Philippine islands and the coast of California. One species, which is particularly abundant in the Pacific, is commonly called trepang, and is a favorite article of food with the Chinese.

FIG. 95. *Caudina arenata*, a sea cucumber common on parts of the New England coast. (Drawn from a preserved specimen.)

# CHAPTER VI

## TYPE IV. VERMES

The term Vermes (Lat. *vermis*, a worm), or worms, no longer has a definite scientific significance. It is nothing more than a popular name given to more or less widely different animals, which generally have a shape commonly called vermiform, and it is only in this popular sense that we can use the word in zoölogy to-day. Used in this way, however, it is a convenient term for keeping together several groups which, at present at least, are better held in this loose relationship than scattered about. At the same time it should be remembered that many zoölogists discard the name entirely, while others apply it to a part of the group. A worm is pretty readily distinguished from the animals we have considered up to this point by its striking bilateral symmetry, and its sharply differentiated anterior and posterior ends, — the head containing a mass of nerve cells, which is commonly called the brain. From the types which we shall study after the Vermes, this type is distinguished chiefly by negative characteristics, *i.e.* by the absence of structures which occur in the others. The Vermes, through one or another of their several subtypes, show relationships to almost all the larger groups of animals, relationships in part structural, but for the most part embryological, — by means of their larvæ. Beyond these few points little can be said in behalf of the type Vermes as a whole, and it is necessary to divide it into several subtypes, which by many zoölogists are considered distinct types.

### SUBTYPE I. PLATYHELMINTHES

The Platyhelminthes (Gr. πλατύς, flat, and ἕλμινς, worm) are for the most part distinctly flattened worms, although there are some flat worms which we can no longer place in this group.

The subtype presents, in the case of some structures in the body, a less highly developed condition than that which we find in the Echinodermata, while on the other hand some organs are more highly differentiated than in the latter group. On the whole, zoologists consider the Platyhelminthes most closely related in structure to the Cœlenterata. Like them, they have no distinct body cavity, and the younger stages in the development of some of the flatworms are significantly like some of the Cœlenterata. But beyond these points there are great differences.

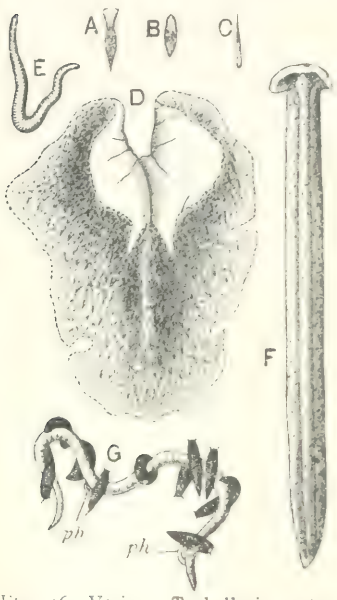



FIG. 96. Various **Turbellaria**, natural size. A, [illegible]; B, [illegible]; C, *Monocelis*; D, *Thysanozoon*; E, *Acmostomum*; *demus*; F, *Bipalium*; G, *Polycelis*. (After von Graff, from Parker and Haswell's Text-book.)

These worms always have a dorsal and a ventral surface, and an anterior and a posterior end. Within the body are discrete groups of nerve or ganglion cells, lying for the most part near the anterior end, where they form a sort of brain, and such groups of nerve-cells occur in none of the Cœlenterata or of the Echinodermata. In shape the Platyhelminthes vary greatly; many are elliptical or oval, while others are more or less elongated. They are nearly all hermaphroditic, and, like the worms in general, are found in fresh or salt water, in moist places, and as parasites within or on the bodies of other animals. Three classes are readily distinguished, strikingly different in external appearance, but pretty closely related to one another.

## CLASS I. TURBELLARIA

The Turbellaria (Lat. *turbo*, a whirling) are for the most part free-living Platyhelminthes. They derive their name from the fact that the body is covered with cilia, so that as they move through the water one may see small plants and animals swept

away by the currents which the motion of the cilia produces. They occur in fresh and salt water, while a few are parasitic, and some live in moist places on the land. The fresh-water species are mostly small, many of them microscopic; in salt water we find species which attain a length of from two to five centimeters (Fig. 96), and among the land Turbellaria individuals have been found in the tropics, thirty-five centimeters in length; but most of the representatives of this class are small. The anterior end of the body is not sharply marked off from the rest to form a head, but contains the brain, and is the most sensitive region. On its dorsal surface are the eyes, usually two lying near the brain, but in some cases there are more. In some Turbellaria a single otocyst is present, and sometimes there is a pair of short tentacles. On the ventral side of the body is the mouth (Fig. 97), which lies in the median longitudinal axis of the body, but in some cases near the anterior end, in some near the middle, and in others near the posterior end. In the Turbellaria, as in all the other Platyhelminthes, an anus is absent. Posterior to the mouth there may be a single genital opening, common to the two sets of reproductive organs, or there may be two openings, one for each sex, one being anterior to the other.

FIG. 96. [illegible] from Naples, ventral aspect; may attain a length of seven centimeters; orange colored. (Drawn from a preserved specimen.)

Of the internal organs (Fig. 98), the most important for the further classification of the Turbellaria is the digestive system. This exhibits in general three types. In its most elementary condition, which occurs in some of the small marine species, there is no alimentary canal bounded by a definite wall, but the mouth opens more or less directly into a mass of loosely arranged cells, which constitute the so-called parenchyma, and there digestion takes place. In other species the mouth opens into a straight tube lying in the median longitudinal axis of the body, and extending both anterior and posterior to the mouth opening; and in still other cases the alimentary canal is greatly branched throughout

the whole structure of the body. Often the mouth does not open directly into the digestive portion of the alimentary canal, but instead into a pharynx, which may sometimes be protruded to a considerable extent through the mouth. The excretory system consists of numerous branched tubules which open in various ways to the outside. The reproduction is usually sexual, and in some cases curiously shaped larvæ are produced. In some few species asexual reproduction occurs by a process of transverse division; the individuals formed in this way usually remain connected with one another for a short time, so that they look like a worm made up of a series of similar segments, or like a colony of worms (Fig. 99); but eventually they all separate and each becomes a distinct, complete individual.

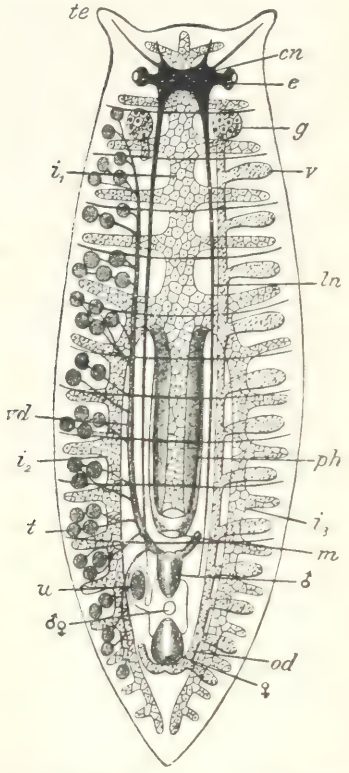



FIG. 98. General structure of a **Turbellarian.** (The male reproductive organs have been omitted from the right side of the diagram, the greater portion of the female from the left.) *cn*, brain; *e*, eye; *g*, ovary; $i_1$, median limb of intestine; $i_2$, left limb; $i_3$, right limb; *ln*, longitudinal nerve-cord; *m*, mouth; *od*, oviduct; *ph*, pharynx; *t*, testes; *te*, tentacles; *v*, vitelline or yolk glands; *vd*, vas deferens; *u*, uterus; ♂, penis; ♀, vagina; ♂♀, common genital opening. (After von Graff, from Parker and Haswell's Manual.)

## CLASS II. TREMATODA

The Trematoda (Gr. τρηματώδης, having holes) resemble the Turbellaria with such differences as are brought about chiefly by a parasitic life, for all the representatives of this class are parasites, and nearly all are hermaphroditic. There are both ectoparasites, living on the outside of other animals, and entoparasites, living within other animals. Cilia are absent from the surface of the body in the adult, and eyes occur in some of the ectoparasites only, while

suckers are always present by means of which they may attach themselves to the host. It is the presence of these suckers which has furnished the name of the class, and we find them, as we should expect, much more numerous in the ectoparasitic species than in the entoparasitic, for the former require a much firmer attachment than the latter. The entoparasites always have one sucker which surrounds the mouth at the anterior end of the body, and this may be the only sucker present; but generally there is a second farther back on the mid-ventral line (Fig. 100). In the ectoparasites there is often a sucker on each side of the mouth and several others at the posterior end of the body. Many of the Trematoda are parasitic on the skin or the gills of fishes and other aquatic animals, and many others are found within the bodies of the higher animals, in various parts of the alimentary canal, in the blood system and the excretory system.

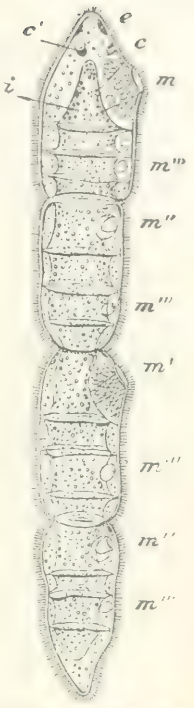



FIG. 99. *M[illegible]* in process of budding. *c*, *c'*, ciliated grooves; *e*, eye-spot; *i*, intestine; *m*, *m'*, *m''*, *m'''*, mouth. (After von Graff, from Parker and Haswell's Textbook.)

FIG. 100. *Distomum hepaticum*, natural size; ventral aspect. *excr*, excretory pore; *mo*, mouth; *repr*, reproductive aperture; *sckr*, posterior sucker. (After Parker and Haswell.)

Some of the entoparasites produce serious diseases in their hosts. A number occur in man, more particularly in the tropics, while the most troublesome of all are probably the flukes, especially the liver fluke of the sheep, *Distomum hepaticum* (Figs. 100 and 100 bis), which in England alone has caused the death of millions of sheep. A similar species, somewhat larger, is found in the liver of the red deer in America. The liver fluke of the sheep is oval or leaf-shaped and attains a length of from two to three centimeters, while the fluke of the deer may be as much as ten centimeters long. The mouth is at the anterior end of the body, surrounded by a sucker, and a short distance posterior to it on

the mid-ventral line is the genital opening; there may be a single opening for the two sexes or a separate one for each, lying side by side. A short distance posterior to the genital pore is the ventral sucker, and at the extreme posterior end of the body lies the opening to the excretory system. The mouth leads into a muscular pharynx succeeded by a short œsophagus, which connects with the U-shaped intestine, in some cases with numerous lateral branches and with no anal opening. The excretory system consists of branched tubules opening posteriorly, and the nervous system resembles that in the Turbellaria. The reproductive organs are very highly developed and self-fertilization seems to be the rule.

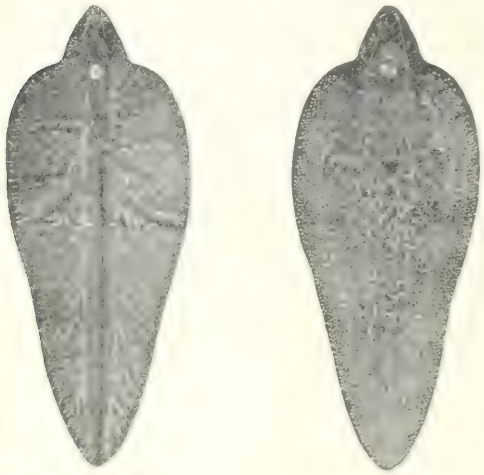


FIG. 100 bis. *Distomum hepaticum*, showing the anatomy; the ventral sucker appears as a white disc. 1, the dark tubes represent the excretory system opening by a pore at the posterior end of the body; the lighter tubes form the digestive tract. 2, the white dots are the testes, which connect with two long tubes, the branching tubes in the center constitute the female organs; the nervous system is represented by ganglia in the head region and two fine cords passing backward. (Photographed from a Leuckart-Nitsche wall-chart, by the author; permission of Dr. C. Chun.)

The development of the Trematoda is somewhat varied. In most of the ectoparasites it is very simple, — the young when hatched from the egg resemble closely the adult. In most of the entoparasites development takes place in one of two ways: in the one case a ciliated larva is produced which passes into a first host and does not become sexually mature until it reaches its second host; in the other case, of which Distomum furnishes an example, the change is more complicated. The fertilized eggs of the fluke pass out through the alimentary canal and, on coming in contact with the water, the larvæ which have developed within them escape and swim about until they have met a certain species of snail, into whose body they bore their way;

there they develop into asexual individuals which eventually produce, asexually, a second type of larva, the cercaria (Fig. 101), and this is the larva which develops into the adult worm. It makes its way out of the snail and swims about in the water, either becoming attached to blades of grass, upon which it encysts itself, or entering the body of some aquatic animal as an inter-

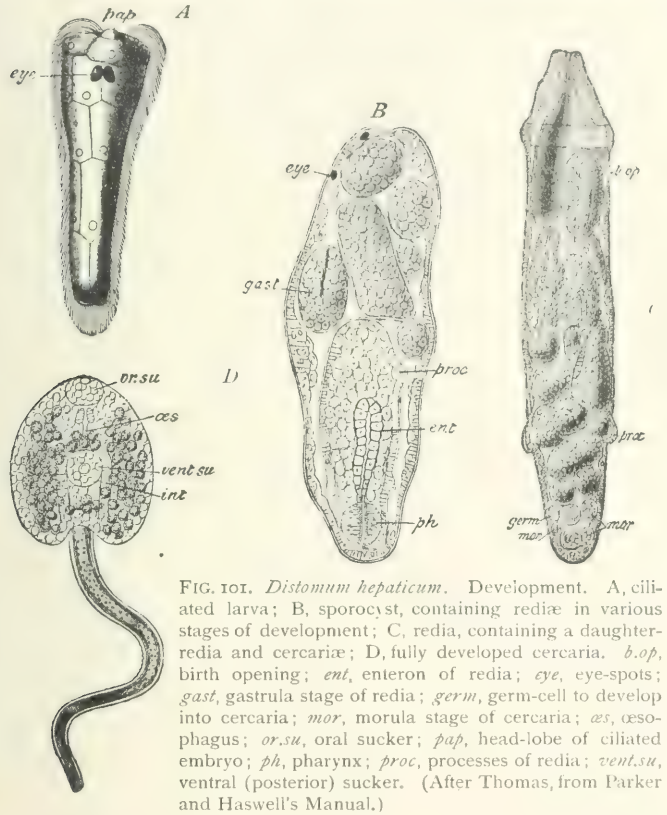



FIG. 101. *Distomum hepaticum*. Development. A, ciliated larva; B, sporocyst, containing rediæ in various stages of development; C, redia, containing a daughter-redia and cercariæ; D, fully developed cercaria. *b.op*, birth opening; *ent*, enteron of redia; *eye*, eye-spots; *gast*, gastrula stage of redia; *germ*, germ-cell to develop into cercaria; *mor*, morula stage of cercaria; *œs*, œsophagus; *or.su*, oral sucker; *pap*, head-lobe of ciliated embryo; *ph*, pharynx; *proc*, processes of redia; *vent.su*, ventral (posterior) sucker. (After Thomas, from Parker and Haswell's Manual.)

mediate host, becoming encysted there. Its final host, usually a vertebrate, receives it either from the grass, or by eating the aquatic animal within which it lies, and then the encysted cercaria escapes from its cyst and develops into a sexually mature trematode. Thus there is here a marked alternation of generations, the sexual with the non-sexual, and three hosts are often necessary for the complete cycle of development.

## CLASS III. CESTODA

The Cestoda (Gr. κεστός, a girdle) are known commonly as the tapeworms, from their usually elongated, bandlike bodies. They are all parasitic in the alimentary canal of vertebrates, and while some resemble greatly the Trematoda, they can always be distinguished by the absence of an alimentary canal or digestive system, the food passing from the alimentary canal of the host

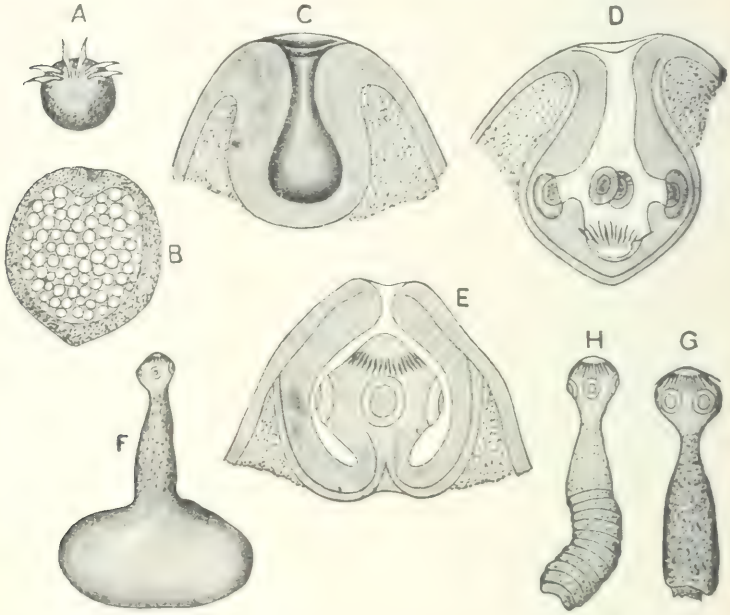



FIG. 102. Development of tapeworm. A, six-hooked embryo; B, proscolex of *Tænia saginata*, the beef tapeworm; C, D, E, successive stages in the formation of the scolex of the same; F, fully developed cysticercus or bladder-worm of *T. solium*, the pork tapeworm; G, scolex of *T. serrata* with remains of the vesicles of the cysticercus; H, young tapeworm of *T. serrata*. (After Leuckart, from Parker and Haswell's Manual.)

directly through the body wall of the parasite. The simplest Cestoda have no organs for attaching themselves to their host, and their bodies consist of a single piece; they are parasitic for the most part in various fishes and water birds. The more complex and by far the greater number of the Cestoda are provided with an organ of attachment called the head, or scolex. This is usually furnished with from two to four suckers, and sometimes

in addition with a circle of hooks, and thus the scolex may be pretty firmly attached to the wall of the intestine of the host.

Beginning a short distance back of the scolex, the entire tapeworm is divided into parts or segments, usually very numerous, which are very minute near the head and increase in length and breadth toward the posterior end. These segments, known technically as proglottides, are greatly flattened, and each proglottis bears typically, either on one of its flattened surfaces or on one of its margins, a single pore, which is the genital opening common to the male and female reproductive apparatus; the Cestoda are all hermaphroditic. New proglottides are constantly formed by transverse divisions just back of the scolex, and as they increase in size are carried farther and farther away from the head, while the segments at the free end of the worm on reaching maturity separate from the rest and pass out of the body of the host. Each proglottis contains the same organs as every other proglottis, differing only in the degree of development; each possesses the same muscular system, the same rudimentary nervous system, and the same system of reproductive organs. Further, when mature and separated from the others, each proglottis exhibits for a time the power of independent motion, and may crawl about after leaving its host, for some distance. These facts have led many zoölogists to consider the tapeworm as a colony of similar individuals placed end to end.

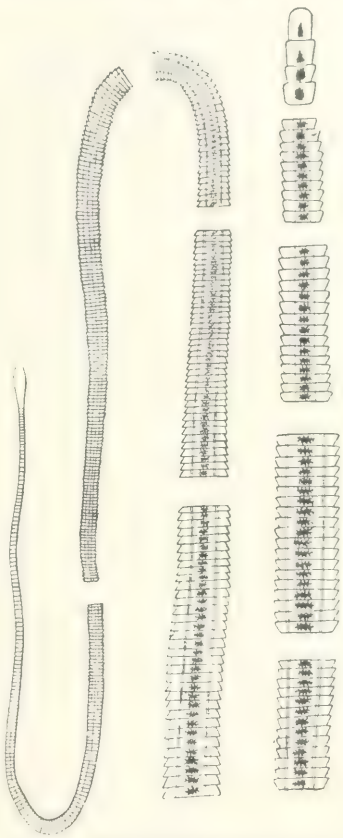


FIG. 103. *Bothriocephalus latus*, the fish tapeworm; portions from different parts of the colony. (After Leuckart.)

On the other hand, the scolex is decidedly different from the

proglottides; it contains ganglionic masses, often well developed, corresponding to the brain, which occur in none of the segments.

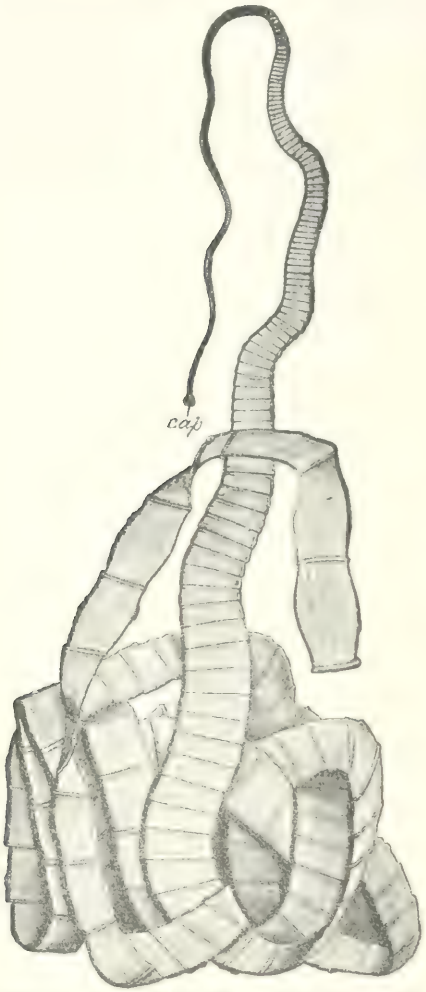



FIG. 104. *Tænia solium*, the pork tapeworm. *cap*, scolex or head. (After Leuckart, from Parker and Haswell's Manual.)

Furthermore, it is clear that in these tapeworms the whole worm corresponds to the simpler Cestoda, which consist of a single piece, for there are intermediate types, where the organs are repeated, but where no external proglottides are formed. These facts would suggest that the tapeworm is a single individual. The tendency to-day, however, is to regard the common tapeworm as a colony like the strobila of the Scyphomedusa, — the scolex thus corresponding to the scyphistoma, and the proglottides to the young medusæ or ephyræ, *i.e.* they become the sexually mature individuals.

The development of the Cestoda takes place in almost all cases by means of two hosts, one in which it always remains an embryo or larva, and the other in which it becomes an adult. The eggs develop into embryos provided with hooks, and on being taken into the alimentary canal of the proper host, they bore through the lining of the intestine and presumably enter the blood vessels, through which they are carried to the various organs of the body, such as the muscles, the brain, the liver; there a cavity

or cyst is formed in the organ, and the embryo develops into what is technically called a cysticercus, or popularly a bladder worm (Fig. 102). It consists of a scolex, to which a saclike

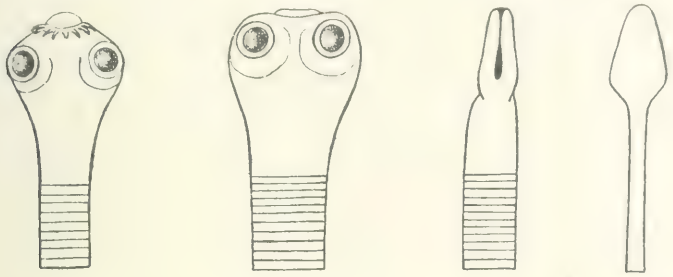


FIG. 105. Scolices of various tapeworms sometimes found in man. 1, *Tænia solium*, the pork tapeworm; 2, *Tænia saginata* (*mediocanellata*), the beef tapeworm; 3, *Bothriocephalus latus*, the fish tapeworm, two views; all enlarged. (After Leuckart, from Hatschek's Lehrbuch.)

enlargement is attached. In its first host the worm never advances beyond this immature condition; but when the first host is eaten by the second and final host, the cysticercus is set free in the intestine, its scolex becomes attached to the wall, the bladder-like enlargement is lost, and proglottides begin to form. The embryonic stages occur in both the vertebrates and the invertebrates, while the adults exist in vertebrates which feed on the first host; the cysticercus of a tapeworm of the cat, for example, is found in the mouse.

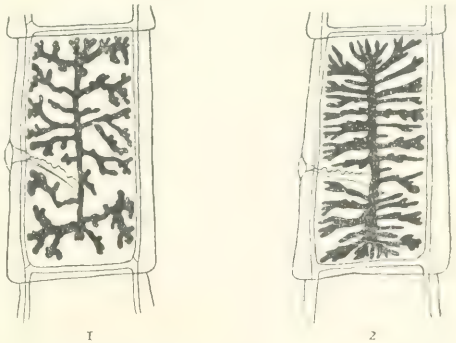


FIG. 106. Ripe proglottides of the two common tapeworms, showing in each the branched uterus as it appears when filled with eggs. 1, [illegible]; 2, *Tænia saginata*. (After Leuckart, from Hatschek's Lehrbuch.)

The Cestoda are of particular interest because there are some which occasionally occur in man. Of these the largest, *Bothriocephalus latus*, is apparently confined to Europe, especially to parts of Russia, Switzerland, and southern France. The cysticercus lives in various fishes, and infection is the result of

eating insufficiently cooked fish. The scolex is flattened and provided with two suckers and no hooks; the worm may be about one centimeter broad and may attain a length of twelve meters, possessing several thousand proglottides. The proglottides are readily distinguished from those of the other human tapeworms by the dark markings on the side, due to the contained eggs (Fig. 103). The most common tapeworm in man is *Tænia solium* (Fig. 104), or the pork tapeworm, so called because the cysticercus lives in pigs; it is most frequent in countries where raw or partially cooked pork is eaten. The scolex is provided with four suckers and a circle of hooks, and each proglottis is provided with a genital pore on one margin. The proglottides resemble those of the beef tapeworm, *Tænia saginata*, whose cysticercus lives in cattle, and insufficiently cooked beef is the cause of infection. The scolex has four suckers and no hooks (Fig. 105), and the proglottides, if rendered transparent, can be distinguished from those of *Tænia solium* by the branchings of the egg filled uterus; in the pork tapeworm these are large and few, in the beef tapeworm they are fine and numerous (Fig. 106). *Tænia solium* may attain a length of three and a half meters, with eight or nine hundred proglottides less than a centimeter broad. *Tænia saginata*, of about the same width, may become seven or eight meters long with twelve hundred to thirteen hundred proglottides. Other tapeworms may occur in man, but these are the most common. Cysticerci are also sometimes human parasites, and the most important of these is the cysticercus of the *Tænia echinococcus* of the dog. The adult is very small, less than half a centimeter long and with usually only three proglottides. The embryos may enter the human body through the handling or kissing of infected dogs, or by similar unhygienic practices. They have been found in the lungs, liver, brain, and other organs, and sometimes produce tumors of great size and weight.

## SUBTYPE II. NEMERTINA

The Nemertina (Gr. Νημέρτης, name of a Nereid) or ribbon worms were for a long time classified with the Platyhelminthes, for the body is usually more or less flattened, but in several

respects they are more highly developed, so that they deserve a subtype for themselves. Like the Turbellaria, the Nemertina are free-living, and the body is soft and covered with cilia; it is always elongated and sometimes greatly so (Figs. 107 and 108). These worms for the most part are marine, though some are found in fresh water and in moist places on land. The mouth is near the anterior end of the body on the ventral side and leads into a straight alimentary canal which terminates in an anus at the posterior end. This is the first group of worms in which an anal opening is present. There is further, at the anterior end, usually on the dorsal side, an opening through which a long tube, the proboscis, may be protruded (Fig. 109). This structure is characteristic of the Nemertina. It lies within the body in a sheath on the dorsal side of the alimentary canal and has a band of muscle fibers attached to its deeper end, by means of which it may be drawn back into the body after it has been protruded. When projected, it is turned inside out, and in some cases the free extremity is armed with one or more spines or stylets, so that it may serve as an organ of defense; in some cases it may be poisonous, and it may have a tactile function.

FIG. 107. *Nemertes neesii*, one of the Nemertina found on the coasts of Great Britain. (After McIntosh.)

In the Nemertina, again, we find, for the first time among the worms, a distinct blood system, which consists of three principal longitudinal vessels, two lateral and one dorsal, and these are connected at the anterior and posterior ends and give off numerous lateral branches. The blood is usually colorless, though in some cases red. It is, then, the presence of these three organs, the anus, the proboscis, and the blood system, that

distinguishes the Nemertina from the Platyhelminthes. In many of the Nemertina the nervous system is more highly developed than in the flatworms proper. It consists of a brain, made up of two ganglionic masses, connected with two nerve cords extending longitudinally through the body and connected with one another by numerous transverse branches. Eyes are present in varying numbers. There is no distinct body-cavity. The excretory system consists of branched tubules, and the reproductive system of simple ovaries, the female germ-glands, and testes, the male germ-glands. The sexes are generally separate, and the development is usually by means of larvæ; a very characteristic larva is the pilidium (Fig. 110), which resembles a Greek cap.

FIG. 108. [illegible], one of the Nemertina found on the Pacific coast; it is bright red in color and often attains a length of two meters. (From a drawing furnished by Dr. W. R. Coe.)

Many of the Nemertina are very small, only two millimeters in length, while some have been found over thirteen meters long and less than one centimeter broad; but all are very contractile and extensible. The colors vary greatly and are often very beautiful, while some species are very curiously marked with longitudinal and transverse lines of contrasting colors (Fig. 111). Even when carefully handled the body breaks up into several pieces, so that it is often difficult to secure an entire animal; under favorable circumstances the pieces may develop into complete worms.

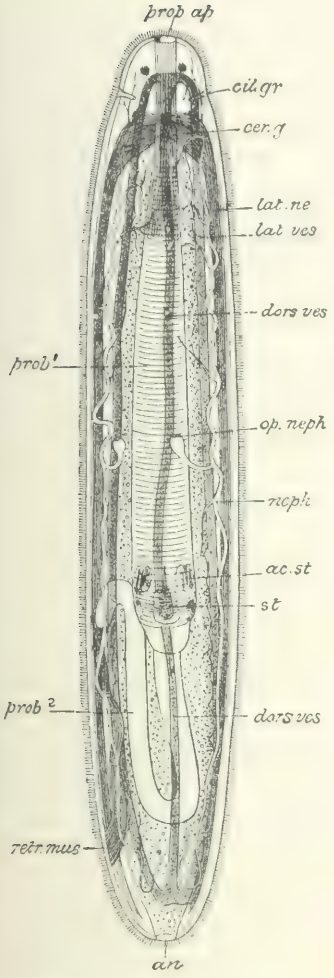



FIG. 109. Young *Tetrastemma obscurum*. *an*, anus; *ac.st*, accessory stylet; *cer.g*, brain; *cil.gr*, ciliated groove; *dors.ves*, dorsal vessel; *lat.ne*, lateral nerve; *lat.ves*, lateral vessel; *neph*, nephridium; *op.neph*, nephridial opening; *prob*[1], eversible part of proboscis; *prob*[2], non-eversible part of proboscis; *prob.ap*, aperture for the protrusion of the proboscis; *retr.mus*, retractor muscle of proboscis; *st*, stylet. (After M. Schulze, from Parker and Haswell's Manual.)

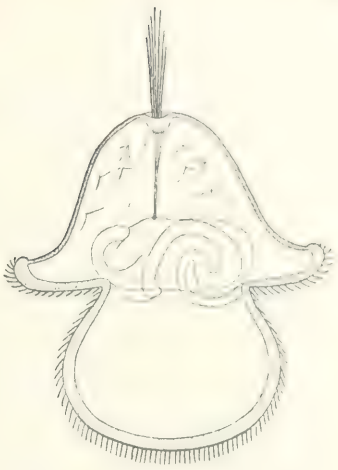


FIG. 110. Pilidium larva of one of the Nemertini; lateral aspect, highly magnified. (Drawn from life by the author.)

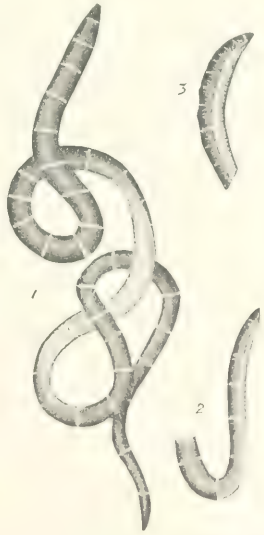



FIG. 111. *Micrura verrilli*, one of the Nemertina found on the Pacific co— dorsal surface violet, tip of head bright red, transverse bands and ventral surface white. 1, entire worm, reduced; 2, anterior end extended, side view; 3, anterior end contracted. (From a drawing furnished by Dr. W. R. Coe.)

## SUBTYPE III. NEMATHELMINTHES

The Nemathelminthes (Gr. *νῆμα*, thread, and *ἕλμινς*, worm), or threadworms, are readily distinguished from the two preceding types by their cylindrical bodies, which usually are very long in proportion to their diameter and tapering at the ends. Internally the chief difference lies in the well-marked body-cavity. The sexes are usually separate, and in the few species which are hermaphroditic the individuals are first male, producing spermatozoa only, and in later life female, producing ova only. Most of the Nemathelminthes are parasitic, chiefly on animals, but in some cases on plants, though many are free-living, occurring in fresh and salt water and in moist earth. Two classes are generally included under this group, but they differ from one another in several points of considerable importance, so that some zoologists are inclined to place them in separate subtypes.

### CLASS I. NEMATODA

The Nematoda (Gr. *νηματώδης*, threadlike) are long, threadlike worms, varying from practically microscopic individuals to the Guinea worm, which may be from thirty centimeters to two meters long. They are provided with a mouth at the anterior end of the body, leading into an alimentary canal, which terminates at the anus on the ventral side near the posterior end. The surface of the body is smooth, and eyes occur in the free-living species only. The excretory organs are small tubes, and the reproductive organs are likewise very simple, consisting in both sexes of elongated tubules lying in the body-cavity, which open in the female near the middle of the body on the ventral side, and in the male at the posterior end, usually near the anus. The males are generally much smaller than the females.

Most of the free-living Nematoda are small. The vinegar eel, which sometimes occurs in vinegar and paste, is only one or two millimeters long. As an exception, there is one genus, Gordius, usually classified with the Nematoda, which may attain a length of fifteen centimeters; it lives in fresh water, while the immature stages of its development are passed in the bodies of various water animals which serve as its host. Several of the parasitic

Nematoda are of much general interest. There are some which are parasitic on the roots of plants, where the young worms bore their way into the roots, and the plant then forms swellings or galls about them and finally dies (Fig. 112). It is particularly

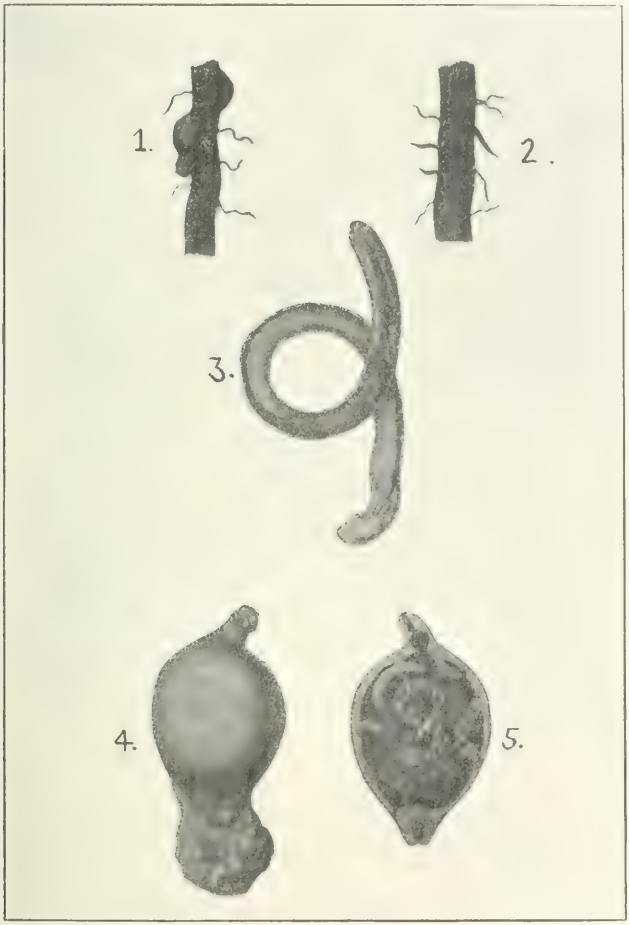



FIG. 112. *Heterodera schachtii*, a roundworm parasitic on the roots of turnips and other garden and greenhouse plants. 1, piece of a turnip root showing two fully developed female worms, which have burst the epidermis of the root, to which they are attached by their heads only; 2, a similar piece of turnip root showing three larvæ just entering by boring; 3, free-living male, fully developed; 4, fully developed female as in 1, more highly magnified, the posterior end of the body surrounded by a gelatinous substance containing three developing eggs; 5, adult female with portion of body wall removed, showing egg-tubes and saccular digestive apparatus. (Photographed from a Leuckart-Nitsche wall chart by the author; permission of Dr. C. Chun.)

FIG. 113. *Ascaris*, a large Nematode parasitic in the intestine of the horse; natural size. (Drawn from specimen.)

troublesome in greenhouses among such plants as the tomato, cucumber, violet, and rose, and in Europe has caused much damage to beets, cabbages, and various grains, such as barley and wheat. Another closely related genus does much damage to wheat by eating the growing ears. Of the animal parasites, several species of the genus Ascaris (Fig. 113) occur in man and various domestic animals in the intestine, probably entering as eggs in the water which the animal drinks. In man they are from ten to thirty-five centimeters long, — in the pig somewhat shorter, in the horse and ox sometimes over forty-five centimeters. Other roundworms, from one to five centimeters long, are common in the alimentary canal of man, particularly in children. The genus Filaria is one of the most dangerous to man in the tropics; it occurs in the blood and lymphatic systems, and is believed to be connected with the condition known as elephantiasis, in which parts of the body increase enormously in size. The Guinea worm belongs to this genus and lives in the subcutaneous tissue, where it forms abscesses which allow the escape of the embryos.

In Europe and North America the most dangerous of the Nematoda to man is the little *Trichina spiralis*, of which the male is about one millimeter long and the female about three millimeters (Fig. 114). The parasite enters man, embedded in the muscle fibers of pork, and if this is raw or insufficiently cooked, the worms rapidly mature in the intestine, and in about a week the young are born alive, each female being capable of producing about a thousand embryos. These make their way through the lining of the intestine and eventually into the various muscles of the body, where they coil up within the muscle fibers and there remain inclosed in a cyst. The disease produced by these worms is called trichinosis, and it is fre-

quently fatal if the number of worms is great. In the pig the trichinæ exist in the muscles in the same condition as in man,

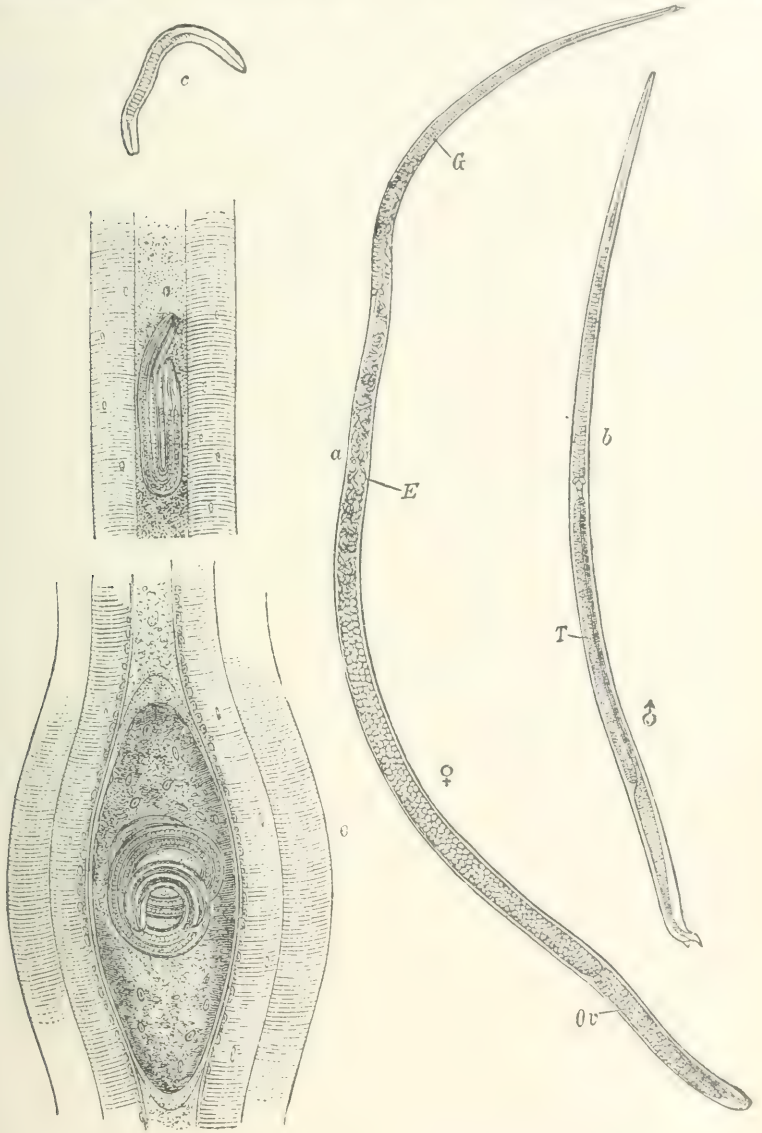



FIG. 114. *Trichina spiralis*, greatly enlarged. *a*, mature female from the alimentary canal; *G*, genital opening; *E*, embryos; *Ov*, ovary. *b*, male; *T*, testis. *c*, embryo. *d*, embryo which has emigrated into a muscle fiber. *e*, the same developed into a coiled muscle trichina, and encysted. (After Claus.)

and they probably gain entrance when the pigs eat other infected animals, such as rats, or the viscera of other trichinous pigs.

## CLASS II. ACANTHOCEPHALA

The Acanthocephala (Gr. *ἀκάνθα*, spine, and *κεφαλή*, head) are all parasitic, for the most part in the digestive tract of fishes, and differ from the Nematoda in two striking respects as well as in several details of structure. In the first place, they have a short, retractile proboscis at the anterior end of the body, provided with numerous chitinous hooks, by means of which the worm attaches itself firmly to the wall of the intestine of its host; in the second place, there is no alimentary canal. A body-cavity is present, and the sexes are separate. The reproductive organs are much more complicated than in the Nematoda, and two hosts are necessary for the development of these animals; the larval or immature condition

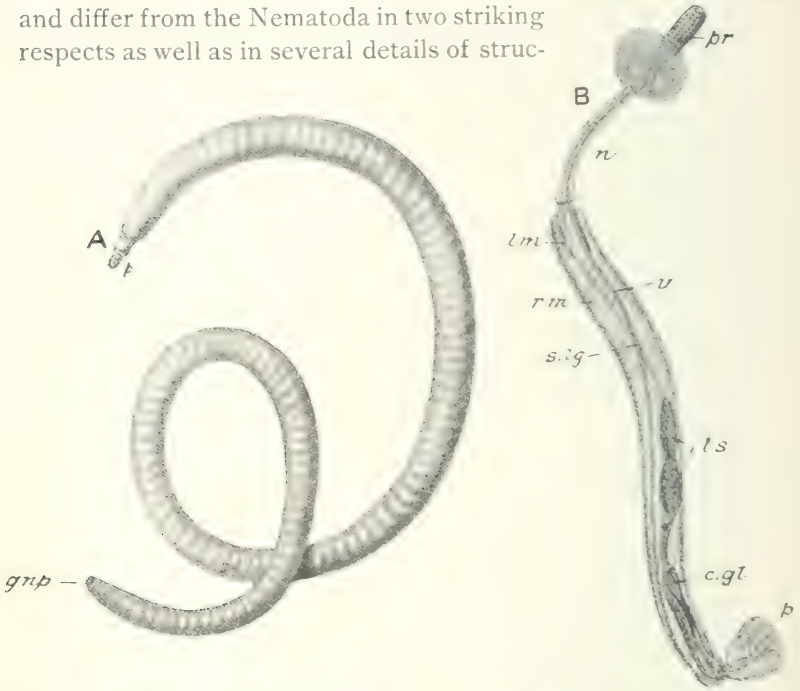



FIG. 115. A, *Echinorhynchus gigas*, natural size; female from pig. B, *Echinorhynchus* [illegible] male from dog. *c.gl*, cement glands; *gnp*, genital pore; *lm*, lemnisci; *n*, neck; *p* and *pr*, proboscis; *r.m*, retractor muscle of proboscis; *s.lg*, suspensory ligament; *t*, testis; *v*, vessel. (After Parker and Haswell.)

is usually passed in some insect or similar small aquatic animal, and enters its second host, where it becomes sexually mature when the latter swallows the first host. Some of the Acanthocephala occur in birds, and the largest is found in the pig (Fig. 115), where it may attain the size of the Nematode, Ascaris, found in the same animal.

## SUBTYPE IV. CHÆTOGNATHA

The Chætognatha (Gr. *χαίτη*, bristle, and *γνάθος*, jaw) have long troubled the systematic zoölogist, for they clearly belong to none of the recognized subtypes of Vermes, and for this reason it seems best, though the group is a small one, to assign it a subtype of its own. They are small, transparent, marine animals, with a rounded body from one to five centimeters long, very slender, and best known through the genus Sagitta, the "arrow-worm," which darts about near the surface of the water (Fig. 116). They possess paired, finlike outgrowths on the sides of the body, projecting horizontally, which vary in number in the different species. The mouth is on the ventral side, near the anterior end of the body, and is provided on each side with a fold, which bears several stiff bristles, directed forward, and these give the name Chætognatha. The alimentary canal is straight, terminating in an anus on the ventral side, but not at the extreme posterior end of the body. A body-cavity is present, divided by a dorsoventral membrane into a right and left half, and further separated by transverse membranes into three compartments or segments, — head, trunk, and tail portions, the anus being at the extreme posterior end of the trunk segment. There are no circulatory or excretory organs, but the nervous system is well developed; it consists of a brain in the dorsal part of the head, from which fibers pass to the two eyes and other sensory organs, and two long connectives extend around the

FIG. 116. *Sagitta hexaptera*, enlarged three and a half diameters; ventral aspect. *a*, mouth; *b*, intestine; *d*, ventral ganglion; *e*, bristles; *f*, spines; *g*, ovary; *h*, oviduct; *i*, vas deferens; *j*, testis; *k*, vesicula seminalis. (From Shipley and MacBride's Zoology.)

œsophagus, joining on the ventral side a large ganglionic mass in the trunk region. The Chætognatha are hermaphroditic; the ovaries, or female germ-glands, lie in the trunk segment, and the oviducts open near the anus. The testes, or male germ-glands, are found in the tail segment.

## SUBTYPE V. ROTIFERA

The Rotifera (Lat. *rota*, a wheel, and *ferre*, to bear) or Rotatoria (Lat. *rotator*, whirler), the "wheel animalcules," are microscopic animals, living for the most part in fresh water or in moist places, though some are marine. They may be found in almost any pool of stagnant water. A few are parasitic, but the greater number are free-living. Most of them are free-swimming, but some are attached, and secrete a sort of tube around themselves for protection. We can distinguish three regions to the body, a head, a trunk, and a tail, but the tail is often greatly reduced. The head region is always provided with numerous cilia very variously arranged in the different groups, and these assist in locomotion and in bringing food to the animal by means of the currents which they set up in the water. On the ventral side of the head is the mouth. The trunk generally possesses a thickened cuticula, which forms a sort of shell; this is called the lorica, and is often provided with spines and ridges, and sometimes exhibits rings suggesting segmentation. The tail is more or less retractile, and is generally provided with a pair of pincer-like appendages at the posterior end for attachment (Fig. 117).

The mouth leads into an enlargement called the pharynx, which is provided with a fairly complicated set of chitinous plates forming the masticatory apparatus. This is succeeded by the stomach, the intestine, and the anus, which opens at the posterior end of the trunk on the dorsal side. There is a large body-cavity, which contains, in addition to the alimentary canal, the single germ-gland, whose duct opens into the posterior end of the intestine. At about the same point is the opening of the excretory tubules, of which there are two, one on each side of the body, more or less convoluted and slightly branched. The nervous system consists of a brain, lying dorsal to the pharynx, and bearing on the dorsal surface a single pigment spot, the eye.

The sexes are separate, and the males are generally much more

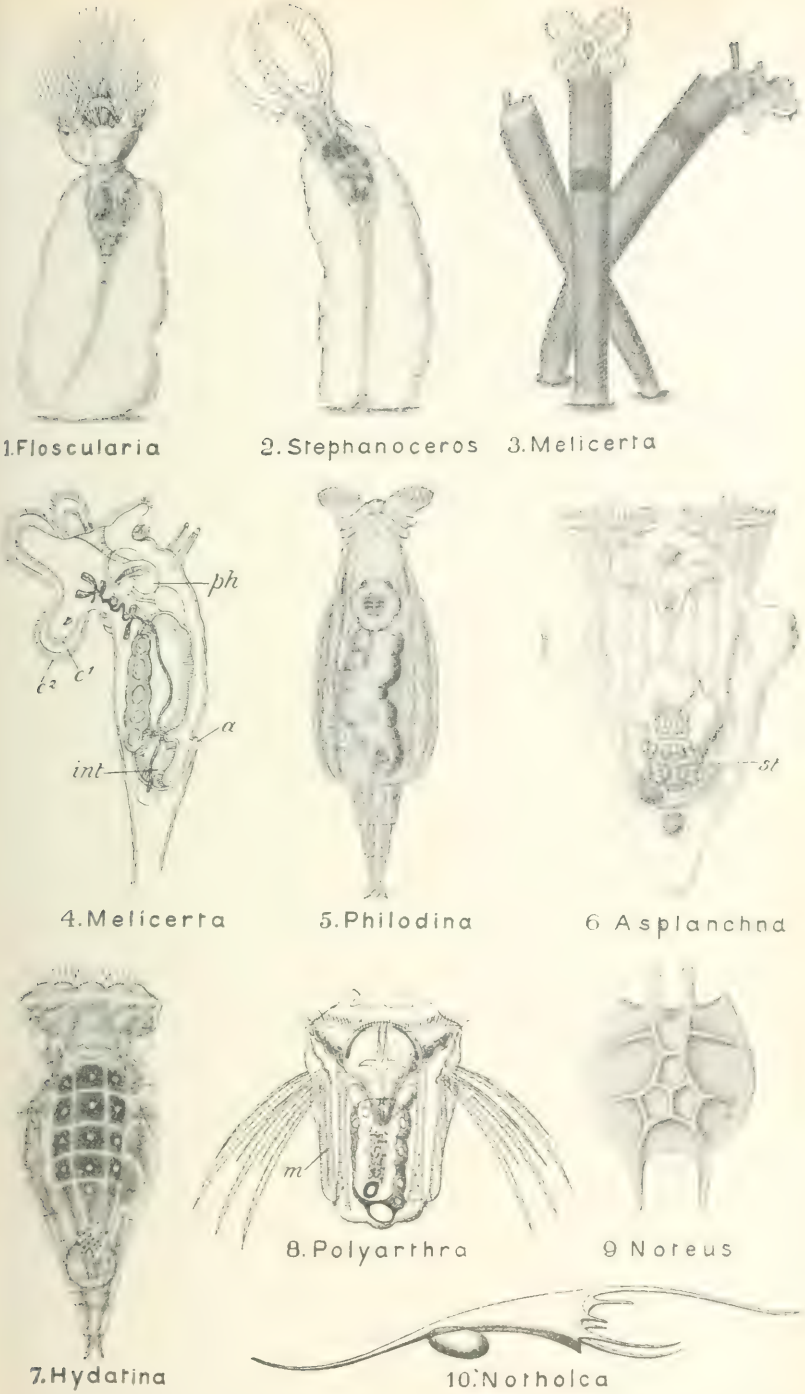



FIG. 117. Various **Rotifera.** 9 and 10 show the lorica or shell only. *an*, anus; *c*, bands of cilia; *int*, intestine; *m*, muscle; *ph*, pharynx. (After Hudson and Parker and Haswell's Text-book.)

degenerate than the females, the alimentary canal often being wanting. For some time it was thought that there were no males, since the females are not only three or four times as large, but also much more numerous. This latter fact is due to the different kinds of eggs produced, and their method of development. During the summer, eggs with thin shells are formed, and of two sizes, the larger developing into females and the smaller into males, and both apparently parthenogenetically, *i.e.* without fertilization. In the autumn thick-shelled eggs are produced, which seem to require fertilization, and in the spring develop into females. A large part of the interest which attaches to the Rotifera is due to the cilia on the head region. These led them at first to be classified with the ciliated Protozoa, but now they show the relationship which these animals possess to the more highly organized worms, many of which possess larvæ strikingly similar in structure to the Rotifera.

## SUBTYPE VI. MOLLUSCOIDEA

The Molluscoidea (Lat. *molluscum*, mollusc, and Gr. εἶδος, form) are sometimes called the Prosopygia (Gr. πρόσω, forward, and πυγή, rump). Their position in the system of classification is somewhat doubtful, but at present they are pretty generally recognized as belonging to the Vermes, though some scientists consider them a type by themselves. The name was due to an inadequate knowledge of the structure of these animals, for the shell, consisting of two valves, which is present in some, resembles very superficially the shell of clams, mussels, oysters, etc., belonging to the type Mollusca; we now know that the Mollusca and the Molluscoidea are not closely related. The members of this subtype are mostly marine, and are attached so that they cannot move about from place to place. In one class large colonies are produced; in one, the individuals live singly. The mouth is at the free end of the body, and near it is the anus. In the neighborhood of the mouth is a tentacle-bearing ridge, the lophophore, often horseshoe-shaped, often circular, the most striking external characteristic of the group. Within, there is generally a distinct body-cavity in which the alimentary canal is suspended. The Molluscoidea may be divided into three classes.

## CLASS I. BRYOZOA OR POLYZOA

The Bryozoa (Gr. *βρύον*, moss, and *ζῶον*, animal), or Polyzoa (Gr. *πολύς*, many, and *ζῶον*, animal), occur to some extent in fresh water, but the majority are marine, living chiefly along the shore and in relatively shallow water, though some have been taken from considerable depths. With one exception they produce colonies which to the naked eye are often strikingly like the hydroid colonies. These colonies occur either as encrusting masses on stones, sticks, seaweeds, or other objects, or as freely branching, dendritic structures, and are generally small, only a few centimeters in diameter; but in some fresh-water species they grow to a diameter of half a meter, and when these get into the water supply of a city and die, they become very objectionable. Each individual in a colony has a secreted, external covering or shell, with an opening through which the anterior portion of the body may be protruded. This shell may be gelatinous, chitinous, or calcareous in structure, and in one suborder there is a chitinous lid, or operculum, attached to the shell, so that the orifice may be completely closed after the animal has withdrawn inside. In this same suborder in which the opercula occur we find curious polymorphic individuals; they are of two kinds: the avicularia, which resemble strikingly the beak of a bird; and the vibracula, which consist chiefly of a long, freely movable lash (Fig. 118). The function of these structures is not known.

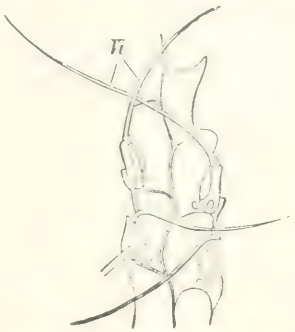


FIG. 118. *Scrupocellaria scr*[illegible] *Vi*, vibracula; magnified. (After Alman, from Claus and Sedgwick's Text-book.)

The lophophore, or crest of ciliated tentacles, is circular or horseshoe-shaped and surrounds the mouth. In a few cases it incloses the mouth and the anus, and individuals in which this occurs are placed in the subclass Entoprocta. Their general structure is much simpler than that of the majority of the Bryozoa, which belong to the subclass Ectoprocta. The alimentary canal is more or less U-shaped, and hangs suspended

in the body-cavity, except in the Entoprocta, which have no body-cavity. There are no excretory or circulatory organs. A

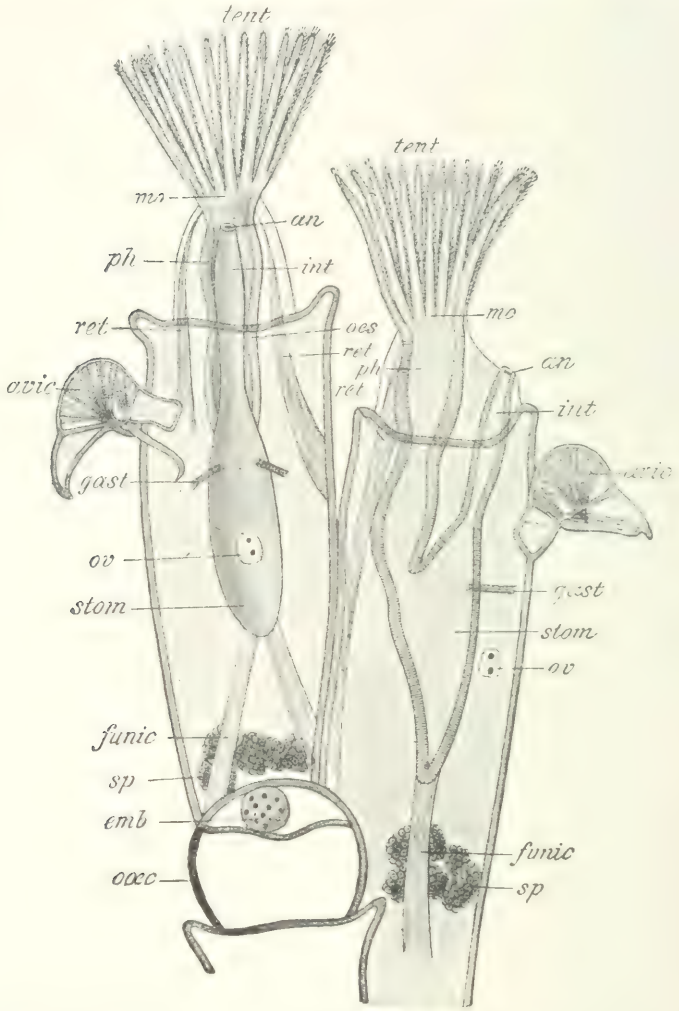



FIG. 119. *Bugula avicularia*. Two individuals or zooids, enlarged. *an*, anus; *avic*, avicularia; *emb*, embryo inclosed in the oœcium; *funic*, funiculus; *gast*, muscle-bands passing from stomach to body-wall; *int*, intestine; *mo*, mouth; *oœc*, oœcium; *œs*, œsophagus; *ov*, ovary; *ph*, pharynx; *ret*, parietal-vaginal muscles; *sp*, spermatidia; *stom*, stomach. (After Parker and Haswell.)

ganglion lying on the œsophagus, between the mouth and the anus, constitutes the chief portion of the nervous system, and

there are no special-sense organs. The Bryozoa are mostly hermaphroditic, with distinct ovaries and testes, and the germ-cells are set free into the body-cavity (Fig. 119).

Reproduction is both sexual and asexual. In the former case a partially ciliated larva is generally produced, such as Cyphonautes, which is like the larvæ of many other worms. Asexual reproduction is by means of budding, which gives rise to the colonies, and also, in many fresh-water Bryozoa, by means of structures called statoblasts (Fig. 120). These generally develop towards the latter part of summer and appear as a group of cells within the body-cavity, which become inclosed in a firm chitinous membrane or shell, biconvex in shape, and sometimes having projecting spines or hooks. The animal generally dies during the winter, and in the spring the contents of the statoblast develops into a new bryozoön. These structures then are of the nature of internal buds, and recall the gemmulæ of the fresh-water sponges.

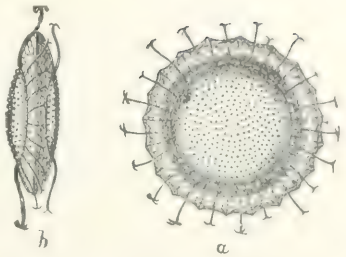



FIG. 120. *Cristatella mucedo*. Statoblasts; *a*, from flattened surface; *b*, from edge; magnified. (After Allman, from Claus and Sedgwick's Text-book.)

FIG. 121. *Phoronis australis*, natural size. (After Parker and Haswell.)

## CLASS II. PHORONIDEA

The Phoronidea (Gr. *Φορωνίς*, name of a king) are represented by a single genus, Phoronis (Fig. 121). They are hermaphroditic, marine worms, living in the sand. They have an elongated, cylindrical body, ten centimeters or more in length, inclosed in a membranous tube within which they can withdraw, and bear a crown of ciliated tentacles on a horseshoe-shaped lophophore. In their adult structure they closely resemble the Ectoprocta among the Bryozoa. Reproduction is exclusively sexual so far as we

know, and ciliated larvæ are produced, which resemble those formed in other groups of the worms.

## CLASS III. BRACHIOPODA

The Brachiopoda (Gr. *βραχίων*, arm, and *πούς*, foot) when examined superficially do not closely resemble the other Mollus-

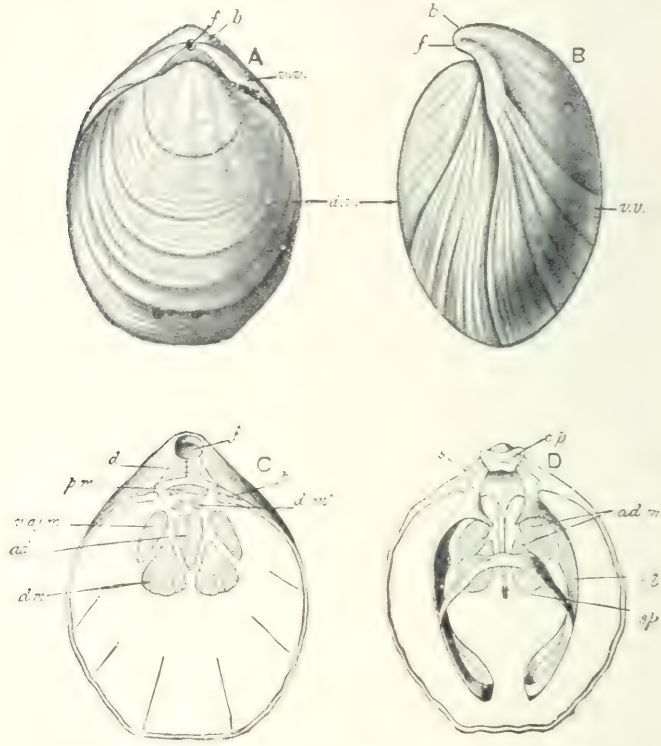



FIG. 122. *Magellania flavescens*. A, dorsal aspect of shell; B, from the left side; C, interior of ventral valve; D, of dorsal valve. *ad.m*, adductor impressions; *b*, beak; *c.p*, cardinal process; *d*, deltidium; *d.m*, divaricator impressions; *d.v*, dorsal valve; *f*, foramen; *p.m*, protractor impressions; *s*, tooth socket; *s.l*, shelly loop; *sp*, septum; *t*, tooth; *v.v*, ventral valve. (After Davidson, from Parker and Haswell's Manual.)

coidea. Their relationship is masked by the presence of a bivalve shell which incloses the body (Fig. 122). They are commonly called lamp shells and are confined to the ocean, attached to rocks and similar objects or partially buried in the sand. They live along the shore and at various depths up to

5500 meters. One valve of the shell covers the dorsal side of the body and the other the ventral, and from what we may call the posterior end of the ventral valve a longer or shorter stalk, the peduncle, generally projects and serves as an organ of attachment. The two valves are connected near their posterior ends by muscles, some serving to close, others to open them, and there is often a hinge. The body of the animal lies in the posterior part of the shell, and folds from the body-wall extend forward, forming a complete membranous lining to the shell.

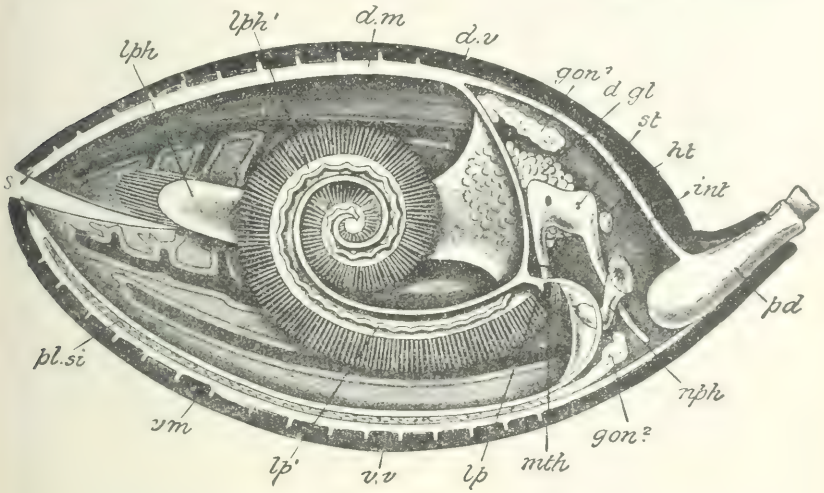



FIG. 123. *Magellania lenticularis.* Sagittal section, *i.e.* vertical-longitudinal. *d.gl*, digestive gland; *d.m*, dorsal mantle-lobe; *d.v*, dorsal valve of shell; *gon*¹, *gon*², gonads; *ht*, heart; *int*, intestine; *lp*, *lp'*, lip; *lph*, lophophore; *lph'*, its coiled process; *mth*, mouth; *nph*, nephridium; *pd*, peduncle; *pl.si*, pallial sinus; *s*, setæ; *v.m*, ventral lobe of mantle; *v.v*, ventral valve of shell. (After Parker and Haswell.)

These folds constitute the mantle, and so the free space within the shell is called the mantle-cavity. In some Brachiopoda the edges of the mantle are provided with short bristles or setæ, which are important because they occur in only one other group of worms, the Annelida.

In the mantle-cavity is the more or less horseshoe-shaped lophophore, bearing ciliated tentacles, which is attached near the mouth, just as in the other Molluscoidea. Often the lophophore becomes very long and is extended into two arms, which are spirally coiled (Fig. 123); these generally are confined within

the shell, but in some species can be protruded beyond the valves. In most cases the arms of the lophophore are supported by a calcareous skeleton, which is attached to the dorsal valve of the shell. Within the body itself we find a body-cavity, which contains the simple alimentary canal, nearly straight or coiled, in some genera ending blindly, in others provided with an anus. There is a simple heart, a pair of excretory organs, and a nervous system consisting chiefly of a nerve ring with ganglionic enlargements surrounding the œsophagus. Organs of special sense are very rudimentary or wanting. Four germ-glands are usually present, some genera being hermaphroditic, others having the sexes separate. In their development larvæ are formed which resemble closely some other worm larvæ. One point of special interest attached to the Brachiopoda is their great antiquity and the fact that some genera living to-day, such as Lingula (Fig. 124), are likewise found in the Silurian. The fossils are much more numerous than the living species. Brachiopoda are common along the eastern coast of the United States at various depths.

FIG. 124. *Lingula*, one of the oldest Brachiopoda; nat. and size. (Drawn from specimen.)

## SUBTYPE VII. ANNELIDA

The Annelida (Lat. *anulus*, ring), the ringed or jointed worms, are the most highly developed animals in this type. The majority of them are readily distinguished from other worms by the ringed appearance of the body, so familiar in the common earthworm. Each animal consists of a series of parts, technically called segments, or metameres, or somites, placed one behind the other, and generally all very much alike except the first and last, which are more or less modified. These rings or segments are not merely superficial markings, as a rule, but correspond to an internal segmentation or repetition of parts. In a

typical annelid are membranes, called dissepiments, which divide the body-cavity into a series of compartments corresponding to the external segments (Fig. 125). These membranes are pierced by the alimentary canal, which passes through the entire length of the body, from the mouth on the ventral side of the first segment to the anus in the last. In many of the segments there is a pair of excretory tubules, the nephridia, or segmental organs, placed symmetrically one on each side of the alimentary canal, and likewise a pair of germ-glands. On the dorsal side of the alimentary canal is a longitudinal blood vessel in which the blood flows from the posterior toward the anterior end of the body, and on the ventral side is a similar vessel in which the blood flows in the opposite direction; these two vessels are connected in each segment by transverse branches. The nervous system consists of a brain, the cerebral ganglia, situated in the first segment on the dorsal side of the alimentary canal. From the brain two nerve cords pass off, one to the right and the other to the left,

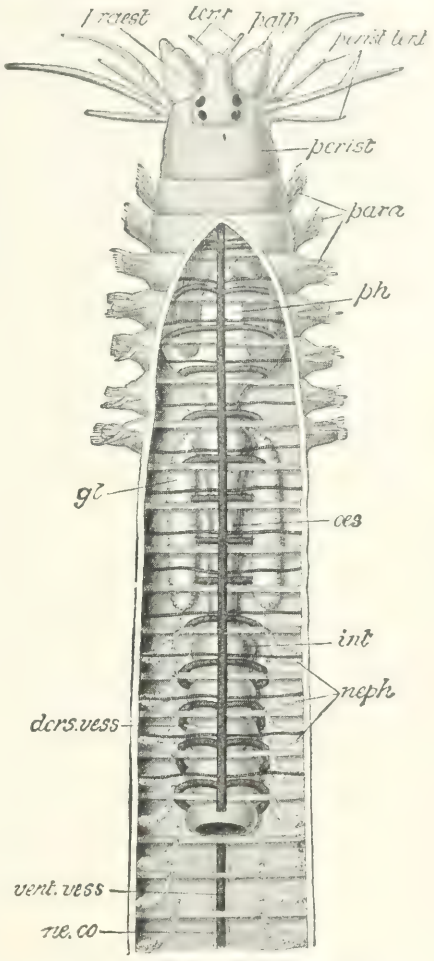



FIG. 125. *Nereis dumerilii.* Semi-diagrammatic view of the anterior portion of the body, with the dorsal body-wall in part removed and also a part of the intestine at the posterior end. *dors. vess.*, dorsal vessel; *gl*, œsophageal glands; *int*, beginning of intestine; *ne.co*, nerve cord; *neph*, nephridia; *œs*, œsophagus; *palp*, palp; *para*, parapodia; *perist*, peristome; *perist.tent*, peristomial tentacles; *ph*, pharynx, with its jaws; *prost*, prostomium; *vent.vess*, ventral vessel. (After Parker and Haswell.)

around the œsophagus or anterior end of the alimentary canal, and meet on the ventral side in a ganglionic enlargement: from this a nerve cord passes backward to the extreme posterior end of the body, running to the ventral blood vessel, and possessing in each segment a ganglionic enlargement from which nerve fibers pass off laterally. Thus the segmentation of a typical annelid is marked externally by rings, internally by a repetition of compartments, nephridia, germ-glands, lateral blood vessels, ganglionic enlargements on the ventral nerve cord, and lateral nerves. And inasmuch as the segments are all essentially alike, these animals are said to have homonomous segmentation.

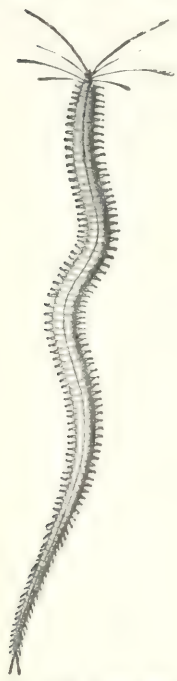


FIG. 126. *Nereis dumerilii*. Natural size. (After Claparède, from Parker and Haswell's Manual.)

Like all worms, the Annelida live in moist places, in the earth or in the water, fresh or salt, or as parasites, though these last are not numerous. Three readily distinguishable classes may be recognized.

## CLASS I. CHÆTOPODA

The Chætopoda (Gr. χαίτη, bristle, and πούς, foot), the bristle-footed worms, are typical Annelida like those described above. They are distinguished from the other classes by the presence of chitinous bristles, called setæ, which are arranged in rows along the side of the body. The locomotion is accomplished in part by these bristles, which act as levers, moved by special muscles, and in part by the general muscular system, which consists of two sets of contractile fibers, one set, the outer, arranged circularly just beneath the skin, and the other, the inner, longitudinally just beneath the circular layer. Thus the body-wall of the worm is said to consist of a dermomuscular sac.

The Chætopoda are made up of two strikingly different groups of worms; in one the setæ are much more numerous than in the other, and this fact has supplied the names for the two subclasses, although there are other equally marked differences.

## SUBCLASS I. POLYCHÆTA

The Polychæta (Gr. πολύς, many, and χαίτη, bristle) are highly developed, marine Chætopoda, very common in the sand and under stones along the shore, and also found in deep water (Fig. 126). The body is generally greatly elongated, sometimes consisting of hundreds of segments, and there is often a distinct, highly differentiated head. This may bear two or more eye and soft processes called palps or tentacles. The mouth is on the ventral side of the head, and opens into a pharynx, often protrusible and provided with strong chitinous teeth. Almost every segment posterior to the head bears a pair of lateral appendages, soft outgrowths from the body-wall, called parapodia. They have the form of flattened, vertical plates, usually divided into two or more lobes arranged in a dorsoventral series, and bear the setæ, which are usually very numerous and long. To the dorsal edge of the parapodia there are often attached long, slender processes, sometimes shorter and richly branched, the branchiæ, or gills, which are the chief organs of respiration. Some curious-looking Polychæta are covered with large overlapping scales, which are really attached to the parapodia and extend completely over the dorsal surface (Fig. 127). In others, like the sea mouse (Fig. 128), the bristles are very long, delicate, hairlike, and iridescent.

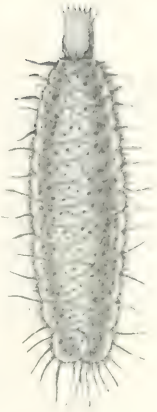


FIG. 127. *Polynöe setosissima*. Dorsal aspect, with pharynx protruded. (After Quatrefages, from Parker and Haswell's Text-book.)

FIG. 128. *Aphrodite aculeata*, the sea mouse. (From Ludwig-Leunis' Synopsis der Thierkunde.)

In this subclass the sexes are

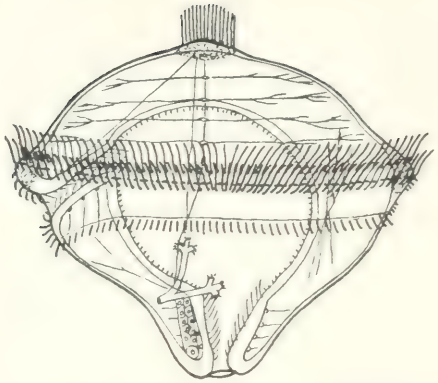


FIG. 129. Trochophore larva of *Polygordius*. Mouth at left, anus below, and preoral and postoral bands of cilia. (After Hatschek.)

separate, and development is always attended by the formation of a larva called the trochosphere, or trochophore, or sometimes Loven's larva (Fig. 129). This larva is very important to the zoölogist because it resembles in some characteristic points the larvæ of other groups of animals, and so is believed to show a relationship between the Annelida and these other types.

The larva is at first more or less spherical and generally provided with one or more bands of cilia. The details of its structure naturally vary greatly in different species of Polychæta. Asexual reproduction may also occur in some genera by simple transverse division (Fig. 130), while in some there is a true alternation of generations. In the latter case the fertilized egg develops into an asexual worm, which by a sort of budding at the posterior end gives rise to sexual individuals.

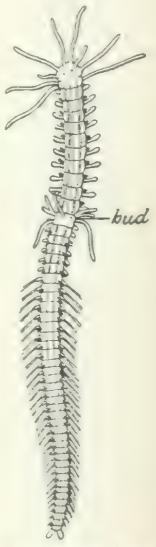



FIG. 130. *Autolytus* [illegible], an Annelid in process of budding; a male bud nearly ready to become detached. (After Agassiz, from Parker and Haswell's Textbook.)

The Polychæta are usually divided into two orders, the Errantia and the Sedentaria. The former move about more or less freely from place to place and possess essentially all the characteristics mentioned in the foregoing description. The Sedentaria are more or less fixed in position and generally form tubes about themselves, sometimes merely particles of sand cemented together by a secretion from their bodies, sometimes chitinous or calcareous structures secreted by the cells of the skin (Fig. 131). Inasmuch as the animals remain permanently in these tubes, the posterior portions of their bodies become more or less degenerate, and the parapodia and other struc-

tures attached to them are very rudimentary. The branchiæ practically disappear except on the segments immediately succeeding the head, and there they are often very long and, like the elongated tentacles on the head, are very beautifully colored so that as one sees them in an aquarium they resemble the most delicately colored flowers, the ugly body of the worm being encased in its tube, which suggests the stem of the plant. The Errantia are carnivorous worms, provided with a protrusible pharynx and teeth; these are wanting in the Sedentaria, which are herbivorous.

FIG. 131. *Serpula* with their tubes. (After Quatrefages, from Parker and Haswell's Manual.)

## SUBCLASS II. OLIGOCHÆTA

The Oligochæta (Gr. ὀλίγος, few, and χαίτη, bristle) are much less highly organized than the Polychæta. They live almost exclusively in fresh water, mud, and in damp earth. They have no sharply differentiated head such as is found in most Polychæta, and consequently palps and tentacles are absent; with few exceptions there are no eyes. Parapodia and branchiæ are likewise wanting, but bristles, or setæ, are present though much less numerous than in the marine worms; they are generally arranged in rows along the sides of the body, and are short, projecting only slightly beyond the surface.

In their internal structure the Oligochæta differ most strikingly from the Polychæta in the reproductive organs. The number of these is greatly reduced, and both testes and ovaries occur in the same individual, usually only one or two pairs of each. But although hermaphroditic, cross fertilization between two individuals takes place, and the eggs are often inclosed in a cocoon formed by a secretion of certain gland cells in the skin of the worm. Each cocoon incloses a number of eggs, and there

FIG. 132. *Lumbricus terrestris*, an oligochæte, slightly more than life size, ventrolateral aspect. 1, prostomium; 2, mouth; 3, anus; 4, opening of oviduct; 5, opening of vas deferens; 6, genital setæ; 7, genital and ventral pore of setæ. XV, XXXII, XXXVII, the fifteenth, thirty-second, and thirty-seventh segments. (From Sedgwick and MacBride's Zoology.)

they develop into young worms without any larval stage; in this respect again they differ from the Polychæta. The Oligochæta possess to a considerable degree the power of regenerating lost parts, and in some of the fresh-water genera asexual reproduction is common, new worms being formed by proliferations at the posterior end of the body. Sometimes the individuals formed in this way may remain attached to one another for a time, thus producing temporary chains or colonies. Here, however, there is no alternation of generations such as sometimes occurs in Polychæta, for each individual is a sexual, hermaphroditic worm.

Many of the fresh water Oligochæta are small, even microscopic, and sometimes have eyes. Those living in the earth are without eyes, and sometimes become very large; the largest known is a tropical earthworm, which attains a length of two meters. The common earthworm (Fig. 132) has a thickened band about the body, comprising several somites about thirty segments back from the anterior end. This band, the clitellum, secretes the capsule or cocoon in which the eggs are laid. The animal lives in little holes in the ground, generally some distance below the surface, and feeds on decaying vegetable matter; this it extracts from the soil, which it takes into its alimentary canal and then deposits the undigested portions as castings, little irregular piles of soil, on the surface of the ground. In this way these small animals turn over large masses of earth and have accomplished almost inconceivable tasks.[1]

[1] See Darwin, "Vegetable Mould and Earthworms."

For the sake of completeness we may mention here two classes of Annelida which are probably somewhat closely related to the Chætopoda. The Myzostomida (Fig. 133) are minute marine worms, parasitic on some Echinodermata, particularly the Crinoidea. The form of the body is generally

FIG. 133. *Myzostoma*. *m*, mouth; *p*, parapodium; *s*, sucker; I–X, marginal cirri. (After von Graff, from Parker and Haswell's Text-book.)

discoidal. There is no trace of external segmentation, but they have five pairs of parapodia, each provided with a single bristle or seta. The Archi-Annelida (Fig. 134) are likewise marine worms, slender, about three centimeters long, and some live freely in the sand, others as external parasites on such animals as the lobster. They are segmented, but without parapodia or setæ, and develop by means of a typical trochosphere larva.

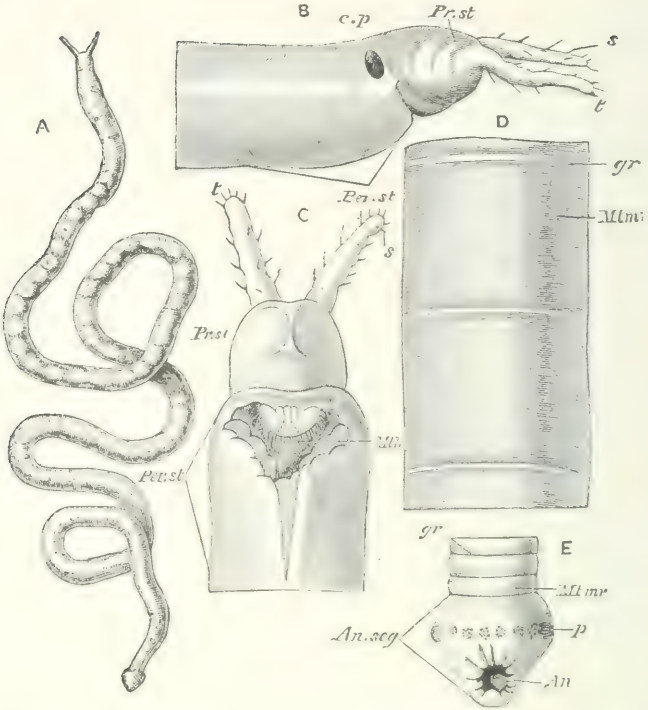



FIG. 134. *Polygordius neapolitanus*, one of the **Archi-Annelida**. A, entire animal, dorsal aspect, enlarged five diameters; B, anterior end, lateral aspect; C, anterior end, ventral aspect; D, portion of body showing the metameres; E, posterior end, ventral aspect. *An*, anus; *An.seg*, anal segment; *c.p*, ciliated pit; *gr*, grooves between metameres; *Mth*, mouth; *Mtmr*, metameres; *p*, papillæ; *per. st*, peristomium; *pr. st*, prostomium; *s*, setæ on tentacles; *t*, tentacles. (After Fraipont, from Parker and Haswell's Text-book.)

## CLASS II. GEPHYREA

The Gephyrea (Gr. γέφυρα, bridge) are classified with the Annelida, although they exhibit no segmentation, either external or internal. They are all marine worms, widely distributed, and live in the sand or in cavities in the rocks. They are capable of only a slow, creeping movement. The body is more or less cylindrical (Fig. 135) and without parapodia, while in a few cases there is a small number of setæ present.

The mouth is at the anterior end of the body, sometimes at the base of a shorter or longer proboscis. In the case of the bright green *Bonellia viridis* the elliptical body of the female is from five to eight centimeters long, while the proboscis is

from twenty to thirty (Fig. 136). The male of this species is only about one millimeter in length and lives as a parasite on the female. In those cases where there is no proboscis, the mouth is surrounded by short tentacles or by a tentacular fold; and the whole anterior part of the body can then be withdrawn by means of strong muscles into the large body-cavity; the anterior portion of the body is therefore called the introvert. Those Gephyrea having a proboscis have the anus at the posterior end of the body; those having an introvert generally have it near the anterior end and on the dorsal side, the alimentary canal being long and twisted within the body-cavity. As there are no dissepiments the body-cavity is a single large chamber. The nephridia are often confined to a single pair, while the blood system resembles in general that of the Chætopoda. The nervous system consists of a brain dorsal to the œsophagus, a circumœsophageal nerve ring and a ventral nerve cord without ganglionic enlargements but with numerous lateral branches. The sexes are separate in the Gephyrea and the development is by means of a trochophore larva, in most instances precisely like the larva of the Polychæta. In some cases

FIG. 136. *Bonellia viridis*. Female with proboscis moderately extended. (After Greef, from Parker and Haswell's Text-book.)

FIG. 135. *Priapulus*. *resp*, posterior papillæ. (After Ehlers, from Parker and Haswell's Text-book.)

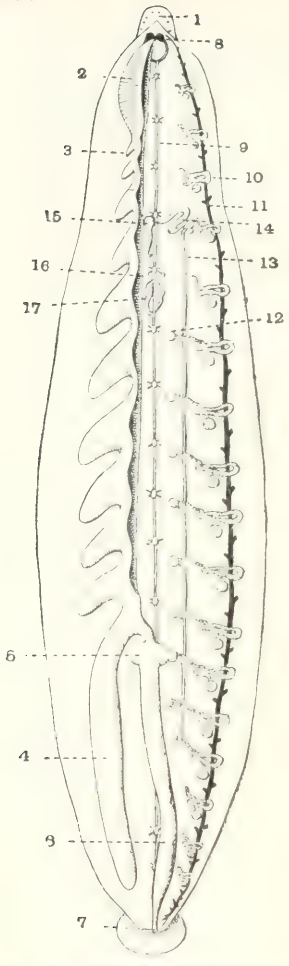



FIG. 137. *Hirudo medicinalis*, the medicinal leech; general anatomy, dorsal aspect. On the left side only the alimentary canal is shown; on the right the greater portion of this has been removed to show other organs. 1, head, with eye-spots; 2, muscular pharynx; 3, first diverticulum of the crop; 4, eleventh diverticulum of the crop; 5, stomach; 6, rectum; 7, anus; 8, cerebral ganglia; 9, ventral nerve-cord; 10, nephridium; 11, lateral blood vessel; 12, testis; 13, vas deferens; 14, prostate; 15, penis; 16, ovary; 17, uterus. (After Shipley and MacBride.)

this larva even becomes segmented, but the segments disappear in the course of the metamorphosis into the adult worm. The Gephyrea are therefore classified with the Annelida chiefly because of this strong resemblance of some of their larvæ to the undoubted Annelida such as the Polychæta.

## CLASS III. HIRUDINEA

The Hirudinea (Lat. *hirudo*, leech), or leeches, live for the most part in fresh water, though some are marine, some live on land, and still others in moist earth. They vary greatly in size, and while the majority are from five to ten centimeters in length, one species is said to attain a length of seventy-six centimeters. The land leeches are common in India, South America, and intermediate countries, and, though only five centimeters long, cause great annoyance to men and horses by their large numbers and persistent attacks. The water leeches suck the blood from all animals living in the water.

In external appearance the Hirudinea differ from the other Annelida in several points. The body is more or less flattened dorsoventrally and is marked by a large number of rings, which, however, do not all correspond to true segments or somites, for there are generally four or five of these external rings to one internal segment. Each animal is provided with two

suckers, a large one at the posterior end of the body, and a smaller one at the anterior end surrounding the mouth. Near the posterior end of the body on the dorsal side is a small opening, the anus, near the posterior sucker. On the dorsal side of the anterior portion of the body are five pairs of small eyes, and in one marine genus there is a row of gills or branchiæ along each side of the body. Some leeches are provided with a sort of proboscis corresponding to the introvert of the Gephyræ, while others have instead three jaws in the mouth, a median and two lateral, which are moved by strong muscles and provided with numerous small, chitinous teeth.

The internal structure differs in many respects from that of the typical Annelida (Fig. 137). The alimentary canal is provided with a large crop or food reservoir, with symmetrically arranged pouches, which is capable of great distention; and when this is filled with blood from its victim, the process of digestion goes on very slowly, a year being sometimes consumed in this function. There are symmetrically arranged nephridia, germ-glands, lateral blood vessels, and nerve ganglia, the nervous system having the same general structure as in typical Annelida. In the Hirudinea the number of segments in the body is constant, there being thirty-four. One great difference between this class and the other jointed worms is found in the fact that the body-cavity is almost entirely obliterated, so that in most cases it can be recognized merely as rather inconspicuous spaces forming a part of the blood system. The leeches are hermaphroditic; there are several pairs of testes whose ducts ultimately connect with the single copulatory organ, or penis, on the median ventral line of the body; there is only a single pair of ovaries. Cross fertilization takes place, and the eggs are deposited in a porous cocoon (Fig. 138) secreted by a sort of clitellum like that of the earthworms.

FIG. 138. *Hirudo*, cocoon. A, surface view; B, in section. (After Leuckart, from Parker and Haswell's Text-book.)

# CHAPTER VII

## TYPE V. ARTHROPODA

The Arthropoda (Gr. ἄρθρον, joint, and πούς, foot) possess more species than any other animal type and include such animals as crabs, scorpions, spiders, centipedes, and insects. They are bilaterally symmetrical, with bodies consisting of a series of segments differing more or less from one another, so that they are said to have heteronomous segmentation, as distinguished from the homonomous segmentation of the Annelida. Typically several segments — in some cases nearly all — are provided with paired appendages attached to the ventral side of the body; these are the organs of locomotion and always consist of a series of parts placed end to end and connected by movable joints, hence the name jointed-footed applied to the type. The function of these appendages varies greatly.

They are variously modified so as to be used for running, walking, jumping, swimming, seizing prey, as well as serving for jaws and other mouth parts, as organs of respiration, and in connection with reproduction. The surface of the body is more or less hardened so as to form a sort of external skeleton or shell; sometimes this is very highly developed, as in the covering of lobsters and crabs, and in other cases the greater portion of the body wall remains relatively soft, as in most spiders, where the chitinous covering is very thin. The sexes are nearly always separate in the Arthropoda; hermaphroditism occurs in a few cases and also parthenogenesis. The external segmentation of the body shows a certain relationship to the Annelida, and internally this relationship is marked by the structure of the nervous system, which is built on the same plan in the two types. The main subdivisions of the Arthropoda are based upon differences in the method of respiration.

## SUBTYPE I. CRUSTACEA

The Crustacea (Lat. *crusta*, shell) are essentially aquatic, consisting of the crabs, lobster, prawns, shrimps, and similar animals; they breathe by means of gills. A few, however, like the land crabs, wood lice, and sand hoppers, live on the land. Crustacea occur both in fresh and salt water, and range in size from microscopic animals to huge crabs with legs over a meter long. The shell or outer covering of the body is secreted by the skin and consists of a chitinous substance, which is usually impregnated with calcium carbonate, except at the joints or boundaries between the segments. This hard shell has to be cast off from time to time in order that the animal may increase in size, and this process, called ecdysis, or moulting, takes place at tolerably frequent intervals while the animal is young, and less and less frequently as the animal grows older.

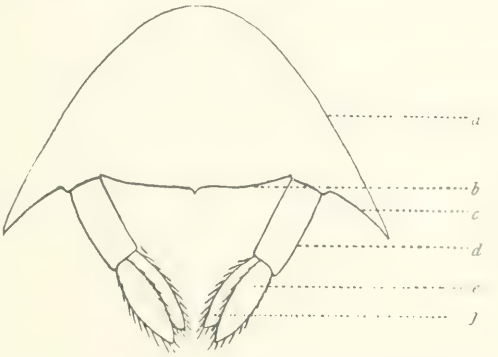



FIG. 139. Diagrammatic cross section through an abdominal segment of a lobster, showing the hard parts. *a*, tergum; *b*, sternum; *c*, pleuron; *d*, protopodite; *e*, exopodite; *f*, endopodite. (Drawn by the author.)

The structure of the appendages is of considerable importance in the Crustacea. They are all built on the same type: attached to the body is a basal piece, to the free end of which two pieces or segments are attached, one on the side toward the median line of the body, the other toward the outside, and these two segments are known as endopodite and exopodite respectively; each may consist of several segments, end to end. Such an appendage is called biramous (Fig. 139). The exopodite is the swimming portion of the appendage, the endopodite is used for walking, and so we find one or the other modified, rudimentary, or altogether lost, according to the predominant method of locomotion in any particular species. The eyes of the Crustacea are different from any that we have found up to this point. Typically

each individual has early in its development, and sometimes throughout life, an ordinary simple eye, unpaired, on the median line of the head. In addition there is a pair of compound eyes, which consist of a large number of parts, each part a structurally complete single eye. These compound eyes are sometimes sessile, *i.e.* on a level with the skin or shell; in other cases they are raised on the tip of a stalk.

There is much variation in the number of segments in the body, but the five anterior segments are always fused together to form the head, which in addition to the eyes has two pairs of feelers, or antennæ, and three pairs of mouth parts. The shape and structure of the body present the widest variation, owing to the very diverse habits of life in this group. While the majority are free-living, many are more or less parasitic, generally external parasites, and present many stages of degeneracy; some are parasitic on other Crustacea. Sometimes only one sex is parasitic, and there may be great sexual dimorphism. They are for the most part carnivorous animals, but some live on dead organic matter, and a few feed on plants. Many minute species are very transparent, and such as live in salt water are often highly phosphorescent. Some Crustacea have a direct development, but the majority have a larval stage very different from the adult. This subtype is divided into two classes.

## CLASS I. ENTOMOSTRACA

The Entomostraca (Gr. *ἔντομος*, cut up, and *ὄστρακον*, shell) include the less highly developed Crustacea, simple in structure and small, though the largest may attain a length of eight centimeters. There is the greatest variation in the general shape of the body and also in the number of segments it contains, even closely allied genera being widely divergent in this respect. The simple unpaired median eye of the larva usually persists throughout the life of the individual, and there is in addition a pair of compound eyes as a rule. Often there grows backward from the head a fold of the integument, forming a sort of covering for the whole or a part of the rest of the body. Such a shieldlike plate is called a carapace; sometimes there are two folds, forming a bivalve shell, like that of a mussel or clam,

hinged on the dorsal side. The outer covering of the Entomostraca is generally not calcareous, but a thin, flexible, chitinous layer. The alimentary canal is a very simple tube, a point in which this class differs strikingly from the next. Finally, in those Entomostraca which develop with a larval stage, the embryo leaves the egg in what is called the nauplius stage. This larva (Fig. 140) is oval in outline, with a simple unpaired

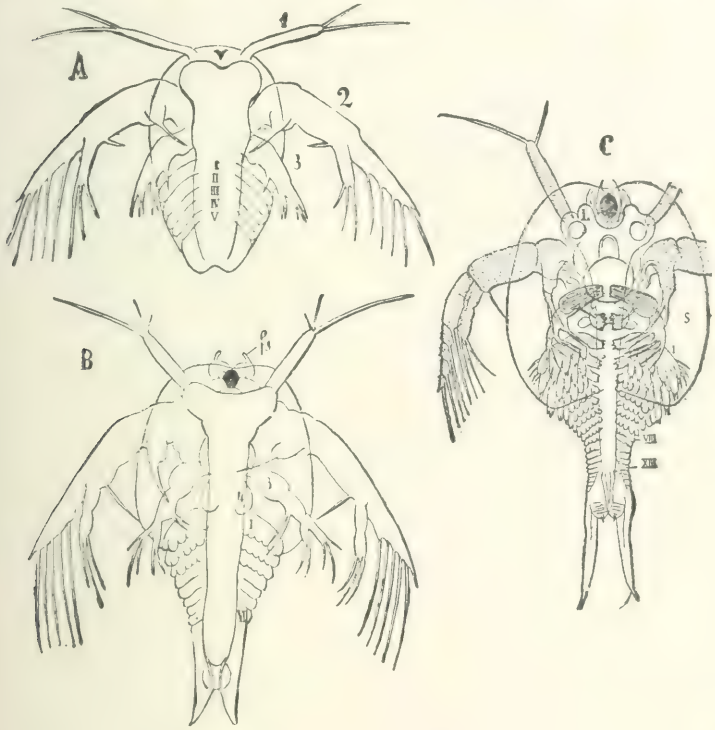



FIG. 140. Three stages in the development of *Apus*. *fs*, frontal sensory organ; *L*, digestive gland; *s*, carapace; 1–4, cephalic appendages; I–XIII, body-segments and appendages. (From Lang's Comparative Anatomy.)

median eye, three pairs of appendages, the first simple, the second and third biramous like the typical crustacean appendage, and posterior to the appendages are traces of segmentation. Several ecdyses metamorphose the larva into the adult. There are four orders in this class, and all are in general sufficiently different externally to be readily distinguishable.

## Order 1. Phyllopoda

The Phyllopoda (Gr. *φύλλον*, leaf, and *πούς*, foot) are mostly fresh-water Entomostraca; a few live in brackish and in salt water. The body is distinctly segmented and exhibits three regions: the head of four or five fused segments, the thorax provided with several pairs of appendages, flattened and leaf-like, and the abdomen, or posterior region, which is without

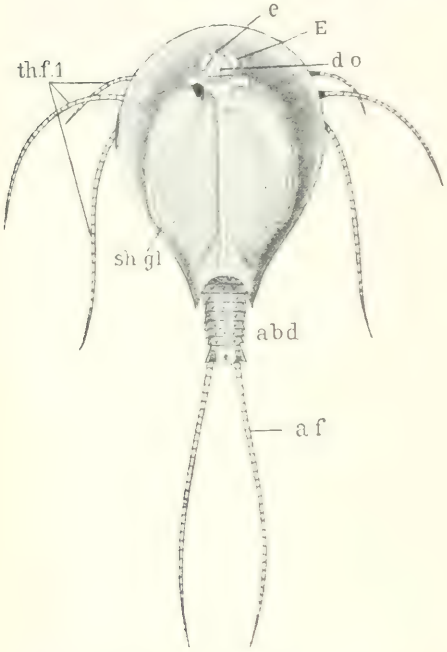



FIG. 141. *Apus cancriformis*. Dorsal aspect; enlarged. *abd*, abdomen; *a.f*, caudal styles; *d*, dorsal organ; *l*, paired eye; *m*, median eye; *sh.gl*, shell-gland; *th.f.1*, endites of first thoracic foot. (From Parker and Haswell's Text-book.)

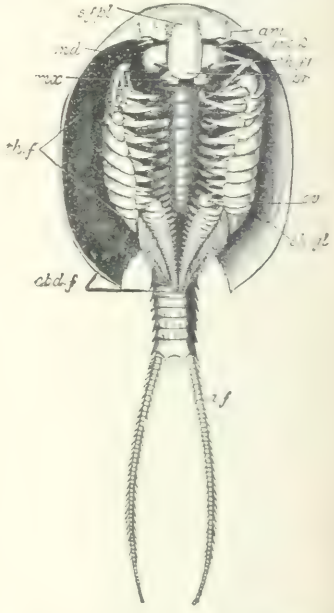



FIG. 142. *Apus glacialis*. Ventral aspect. *abd.f*, abdominal feet; *ant.1*, antennule; *ant.2*, antenna; *md*, mandible; *mx*, first maxilla; *ov*, oviduct; *s.f.pl.*, sub-frontal plate; *sh.gl*, shell-gland; *th.f*, thoracic feet; *th.f.1*, first thoracic foot. (After Bernard, from Parker and Haswell's Manual.)

appendages. Most of the Phyllopoda are almost microscopic in size, but some are several centimeters long. They present the greatest diversity in form. Some, like Apus (Figs. 141 and 142), are flattened dorsoventrally and have a large cephalic carapace which extends backward over the whole thoracic region. The majority have the body compressed laterally, sometimes without

any shieldlike covering, as in Branchipus (Fig. 143), sometimes with the entire body inclosed in a bivalve shell. In some genera the leaflike, swimming appendages become greatly reduced in number, and this is attended with a great increase in size of the second pair of antennæ, which become the chief organ of locomotion. This is well seen in the common fresh-water Daphnia (Fig. 144), one of the water fleas; its peculiar appearance is increased by the fusion of the two compound eyes into one median compound eye.

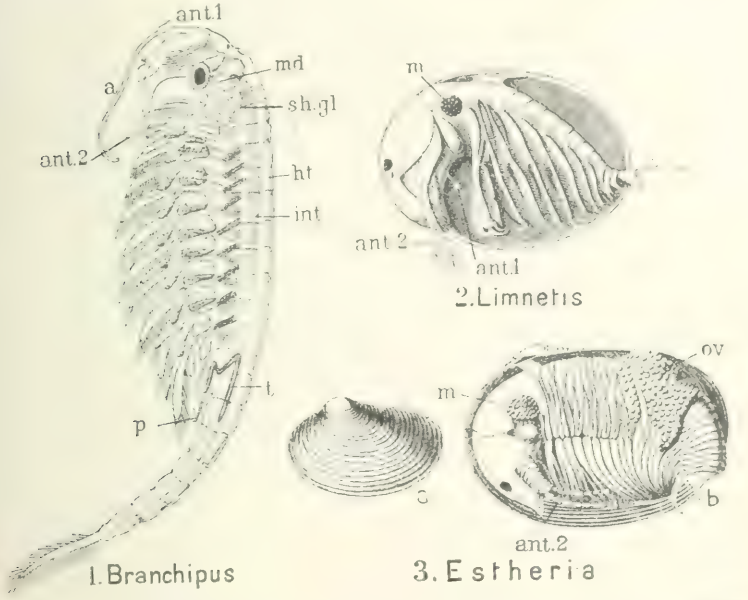



FIG. 143. Three **Phyllopoda.** 3a, shell, external view; 3b, the animal (more enlarged) with one valve of shell removed. *a*, unpaired process from head; *ant.1*, antennule; *ant.2*, antenna; *ht*, heart; *m*, adductor muscle; *md*, mandible; *ov*, ovary; *p*, copulatory appendages; *sh.gl*, shell-gland; *t*, testis. (After Gerstaecker, from Parker and Haswell's Text-book.)

In the Phyllopoda several pairs of the swimming appendages have gills or respiratory organs attached to them. In the female there is often a brood pouch on the dorsal side of the body, in which the eggs develop. Two kinds of eggs are frequently produced, — the summer eggs, thin-shelled, which develop parthenogenetically, and the winter eggs, which are formed in the autumn, require fertilization and remain quiescent during

the winter to develop in the spring. They are still capable of developing even after desiccation and freezing, and in some instances at least this appears to be necessary.

### Order 2. Ostracoda

The Ostracoda (Gr. *ὄστρακον*, shell) are only one or two millimeters long and are found in both fresh and salt water. They

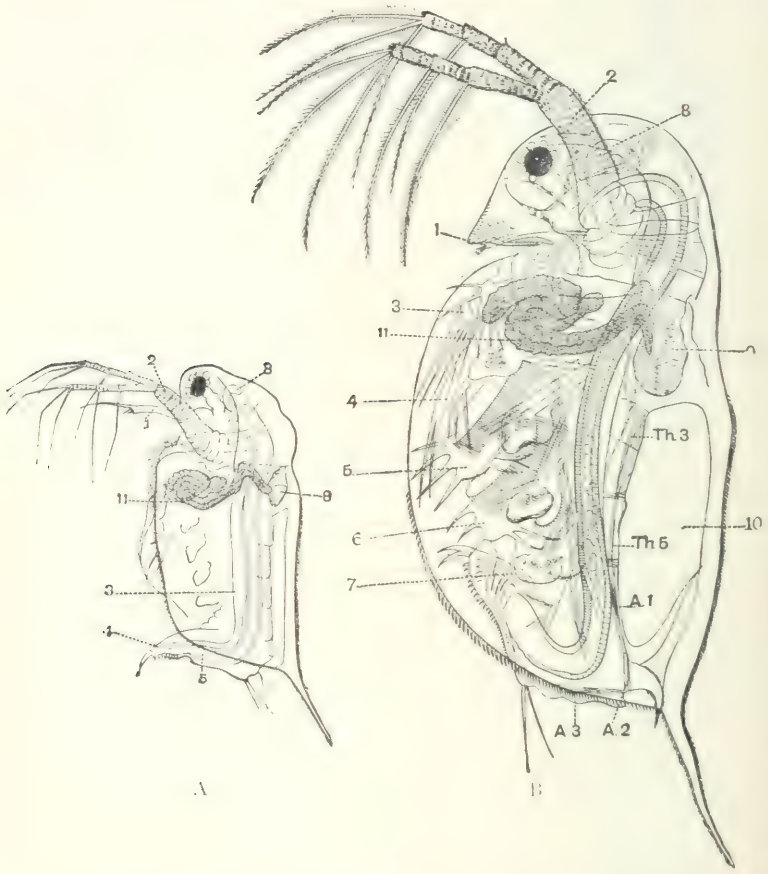



FIG. 144. *Daphnia similis*. A, male, side view, greatly enlarged. 1, antennule; 2, antenna; 3, testis; 4, vas deferens; 5, intestine; 8, liver; 9, heart; 11, shell or maxillary gland. B, female, side view, same magnification as A. 1, antennule; 2, antenna; 3, 4, 5, 6, 7, first, second, third, fourth, and fifth pairs of legs; 8, hepatic diverticulum; 9, heart; 10, brood pouch; 11, shell or maxillary gland; *Th3* and *Th5*, third and fifth thoracic segments; *A1*, *A2*, *A3*, first, second, and third abdominal segments. (After Claus, from Shipley and MacBride's Zoölogy.)

always have a bivalve shell, which may be opened by an elastic ligament on the dorsal side and closed by means of muscles within, passing from one valve to the other. There is a median simple eye and sometimes a pair of compound eyes as well. The number of appendages is seven pairs, five pairs belonging to the head and two to the thorax; the abdomen is short and without appendages. The body is unsegmented and lies completely within the shell. Cypris (Fig. 145) is the most common fresh-water genus.

### Order 3. Copepoda

The Copepoda (Gr. *κώπη*, oar, and *πούς*, foot) are mostly small, but occur in very great abundance in both fresh and salt water. The body is distinctly segmented except in most parasites and is without a shell. The number of segments is pretty constant; in addition to the head segments there are five in the thorax and five in the abdomen. The appendages are confined to the head and the thorax, the latter having four or five pairs, which are biramous. In most species there is only a simple median eye. The common water flea, Cyclops (Fig. 146), found in great numbers in fresh water, is a typical representative of the order; it swims about with a jerky motion, which makes it readily distinguishable, and the females have a pair of elongated sacs filled with eggs attached to the posterior end of the body. Such egg sacs occur in almost all the Copepoda.

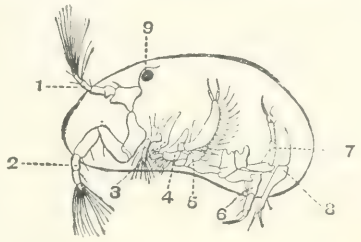



FIG. 145. *Cypris candida*. Lateral aspect; enlarged. 1, antennule; 2, antenna; 3, mandible; 4, first maxilla; 5, second maxilla; 6, first pair of legs; 7, second pair of legs; 8, tail; 9, eye. (After Zenker, from Shipley and MacBride's Zoology.)

The curious parasitic species are among the most interesting in this order. It is generally the female only that is parasitic, the male being free-swimming and very much smaller; they live on various water animals, but mostly on fishes. These parasites often lose all external resemblance to Crustacea, having worm-like bodies with some of the mouth parts modified into hooks for attachment to their host and for sucking organs. Generally

the two long egg sacs are present which are so characteristic of the Copepoda (Fig. 147). In some cases the minute male is practically a parasite on the body of the parasitic female. The

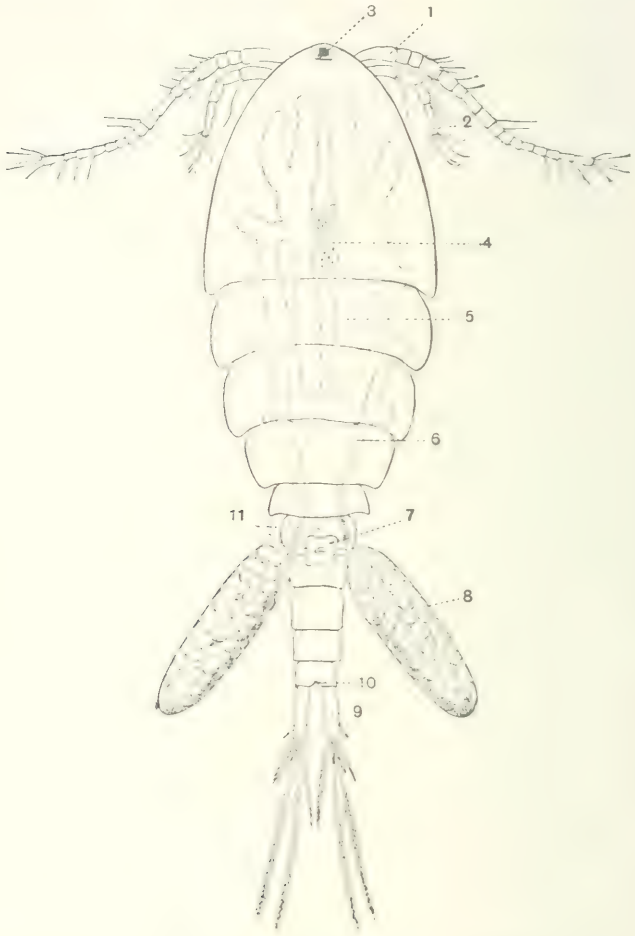



FIG. 146. *Cyclops sp.* Dorsal aspect of female; enlarged. 1, antennule; 2, antenna; 3, eye; 4, ovary; 5, uterus; 6, oviduct; 7, seminal receptacle; 8, egg sacs; 9, caudal forks; 10, anus; 11, compound segment, consisting of last thoracic (with genital opening) and the first abdominal. (Partly after Hartog, from Shipley and MacBride's Zoölogy.)

gills of fishes form a favorite point of attachment for these parasites, which sometimes attain a length of seven centimeters. In one group of the Copepoda the body is greatly flattened

dorsoventrally; there is a pair of compound eyes and a mouth adapted for sucking, as these animals, while parasites externally on the skin of fishes, attaching themselves by suckerlike discs,

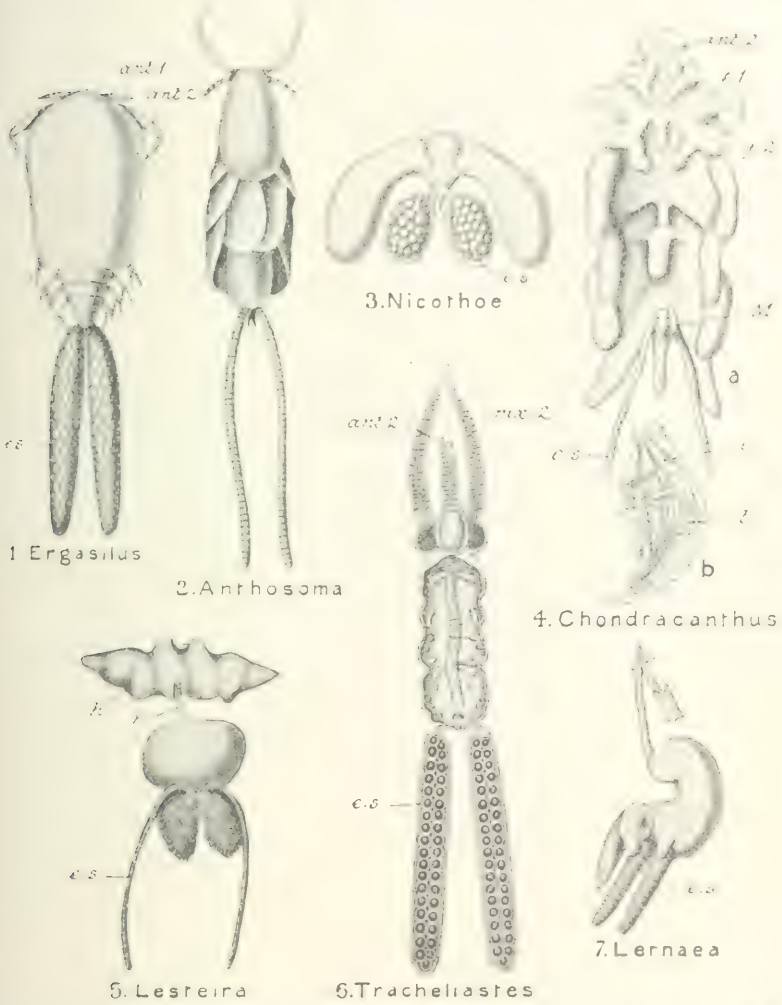



FIG. 147. Various parasitic **Copepoda**, occurring chiefly on fishes. 4a, female; 4b, [illegible] more enlarged. *ant.1*, antennule; *ant.2*, antenna; *e*, median eye; [illegible] thoracic feet; *h*, head; *M*, male; *mx.2*, second maxillæ; *n*, neck. (After Gerstaecker, Claus, Cuvier, and Thompson, from Parker and Haswell's Text-book.)

can move about more or less over the bodies of their hosts (Fig. 148). The Copepoda have a very wide distribution, and

through their great numbers constitute the principal food supply of many fishes and also of the whalebone whale.

### Order 4. Cirripedia

The Cirripedia (Lat. *cirrus*, crest, and *pes*, foot) include all the various kinds of barnacles, which are exclusively marine animals. The most striking difference between these Entomostraca and the other three orders lies in the attached condition of the adult animal and the consequent structural modifications. There are three groups of barnacles: the goose-neck barnacles, which are attached by a longer or shorter stalk, the incrusting or acorn barnacles, which have no stalk, and the parasitic barnacles.

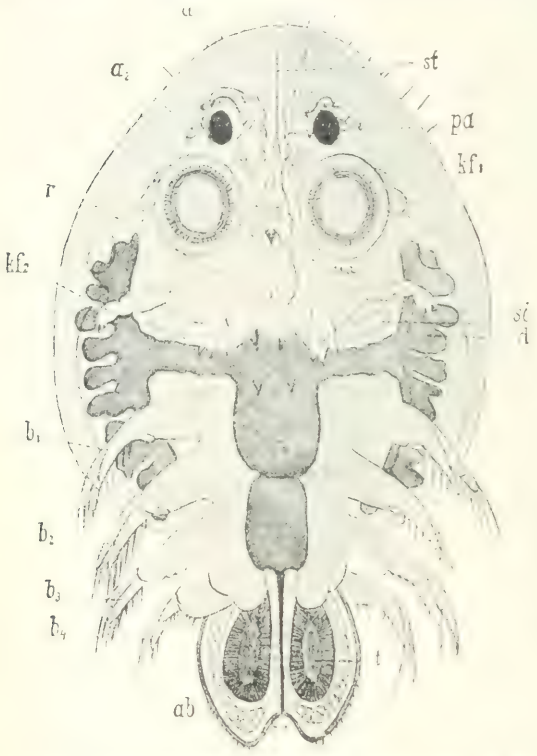



FIG. 148. *Ingolfia* [illegible], a cup louse; young male. $a_1$, antennule; $a_2$, antenna; *ab*, abdomen; $b_1$–$b_4$, thoracic feet; *d*, digestive glands; *kf1*, anterior or suctorial feet; *kf2*, posterior or leglike portion of second maxillae; *pa*, paired eye; *r*, rostrum; *sd*, shell-gland; *st*, stylet; *ts*, testis; *ma*, median eye. (From Parker and Haswell's Text-book.)

The goose-neck barnacles (Fig. 149) are attached by the dorsal side of the head, from which the elongated stalk grows out; they are found most frequently on floating objects, such as logs, sticks, and vessels, or on piles. Inclosing the body of the animal at the free end of the stalk is a sort of bivalve shell containing five calcareous plates. Through the opening in this

shell the feathery appendages may be protruded; of these there are six pairs, attached to the thorax. The body itself does not appear segmented, and terminates posteriorly in an elongated copulatory organ, or penis. Since these barnacles occur so frequently on wood, the belief arose some centuries ago that they were of vegetable origin, while the feathery, thoracic appendages suggested an association with birds, so that many of the earlier writers on natural history maintained with convic-

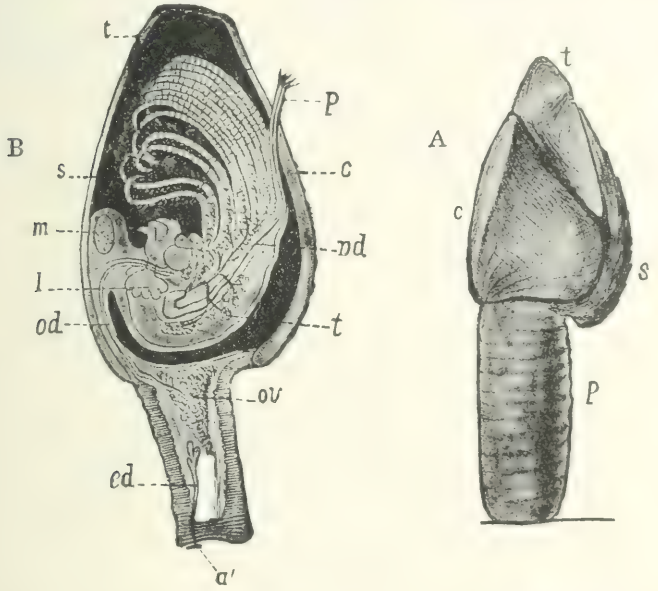



FIG. 149. *Lepas anatifera*, the goose-neck barnacle. A, external view; B, internal structure. *a'*, antennule; *c*, carina; *cd*, cement gland; *l*, digestive gland; *m*, adductor muscle; *od*, oviduct; *ov*, ovary; *P* in A1 peduncle and in B1 penis; *s*, scutum; *t*, tergum and testis; *vd*, vas deferens. (After Darwin and Claus, from Parker and Haswell's Manual.)

tion that geese developed directly from barnacles; one writer asserts that he has seen the process.

The stalkless barnacles have very much the same structure as the goose-neck, but they are provided with a much firmer shell (Fig. 150), the body being surrounded by a sort of wall, often very thick and with sharp edges, and consisting of immovable plates. There are movable plates covering the free or ventral surface of the animal, between which the appendages

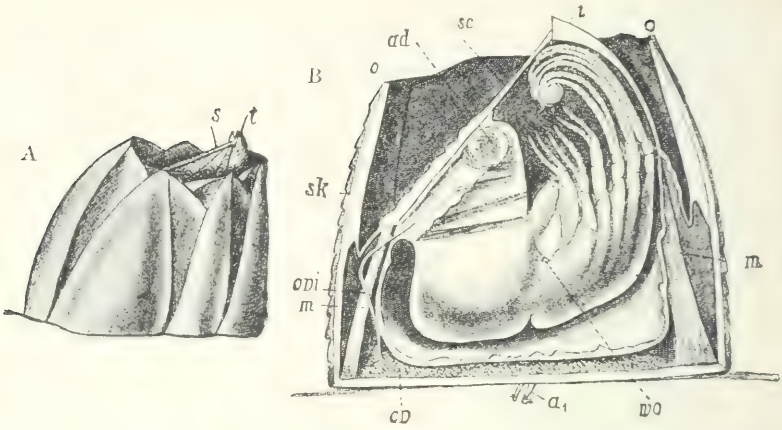



FIG. 150. *Balanus*, an incrusting barnacle. A, lateral external aspect; B, anatomy. *a*, antennules; *ad*, adductor muscle; *m*, muscles of scuta and terga; *o*, edge of parapet; *ov*, ovary; *ovi*, oviduct; *s*, scutum; *sk*, parapet; *t*, tergum; *wo*, female aperture. (After Darwin, from Parker and Haswell's Text-book.)

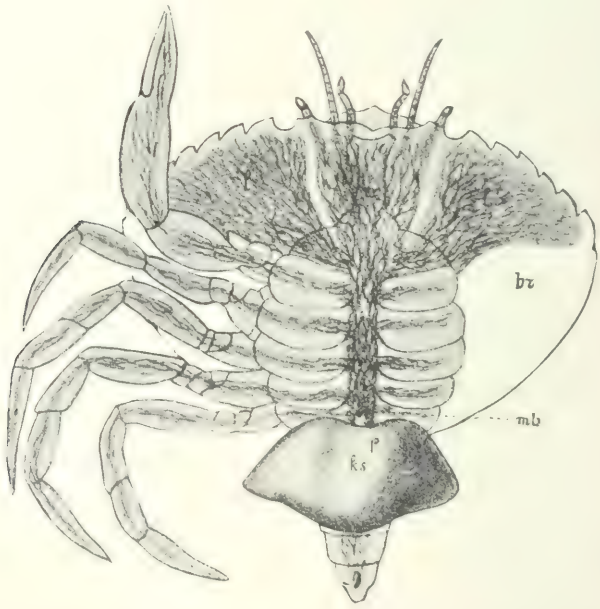



FIG. 151. *Sacculini carcini*, a parasitic barnacle on abdomen of a crab. *br*, branchial region of crab; *l*, hepatic region; *d*, intestinal region; *ks*, body of parasite; *p*, pedunc[illegible]; *mb*, basilar membrane, giving off rootlike processes which extend throughout the body of the host. (After Delage, from Parker and Haswell's Text-book.)

may be extended. Huxley's statement that "a barnacle may be said to be a Crustacean fixed by its head and kicking the food into its mouth with its legs," is very fitting.

The parasitic barnacles are very degenerated in structure (Fig. 151), without appendages, and present no structural evidence of belonging to the Cirripedia; their classification is based upon their development. They live attached to the ventral side of crabs, into whose bodies they send numerous, finely branching processes, which thus obtain nutriment for the parasite. Externally there appears merely a sac, practically filled with the reproductive organs, which is attached to the host by a short stalk.

This is the only group of Crustacea in which hermaphroditism is the rule, this being to a large degree the necessary consequence of the attached condition, though even here cross fertilization often takes place. In a few cases dwarf or pygmy males occur, which are not attached, but generally live within the shells of hermaphroditic individuals, or in a few cases of female individuals; in the latter case, then, the sexes are separate, but with great sexual dimorphism. In their development all the Cirripedia pass through a free-swimming stage, and after ecdysis pass into a stage like the adult Ostracoda, and hence called the Cypris larva. This becomes attached at its anterior end and is metamorphosed into the adult. The hard shell of barnacles is not cast off by ecdysis, but only the delicate, chitinous covering of the appendages and adjacent structures is shed from time to time.

## CLASS II. MALACOSTRACA

The Malacostraca (Gr. *μαλακός*, soft, and *ὄστρακον*, shell) include the larger and more highly developed Crustacea, which are readily distinguished from the Entomostraca by the number of segments in the body. This number is constant, so that there are five in the head, eight in the thorax, and seven in the abdomen; there is one exception to this rule, one subclass having eight in the abdomen. Each segment except the last bears a pair of appendages. The last segment is called the telson. Some or all of the thoracic segments are fused with the head so that we can distinguish a cephalothoracic region

covered by a carapace. There is always a pair of compound eyes, which are sometimes sessile and sometimes stalked. The internal anatomy of the Malacostraca offers one distinguishing point in the structure of the stomach, which is provided with an apparatus for grinding the food; this is never found in Entomostraca. In their development the nauplius stage is passed in the egg membrane, and the larva hatches in a later stage of development; in a few cases there is no larval stage. The Malacostraca may be divided into three subclasses.

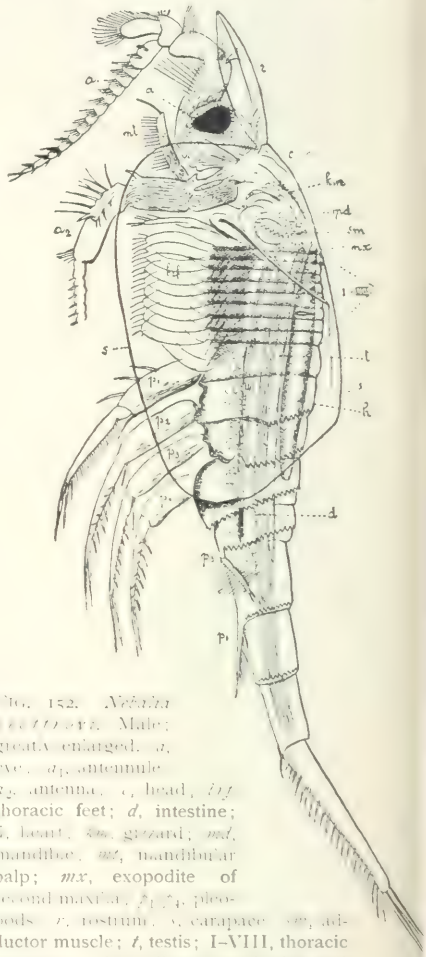


FIG. 152. *Nebalia geoffroyi*. Male; greatly enlarged. *a*, eye; $a_1$, antennule; $a_2$, antenna; *c*, head; *hp*, thoracic feet; *d*, intestine; *h*, heart; *giz*, gizzard; *md*, mandible; *mx*, mandibular palp; *mx*, exopodite of second maxilla; $p_1$–$p_8$, pleopods; *r*, rostrum; *s*, carapace; *sm*, adductor muscle; *t*, testis; I–VIII, thoracic segments. (After Claus from Parker and Haswell's Text-book.)

## SUBCLASS I. LEPTOSTRACA

The Leptostraca (Gr. λεπτός, delicate, and ὄστρακον, shell) constitute a very small group of minute marine Crustacea, which are interesting and important as forming a connecting link between some of the Entomostraca, such as the Phyllopoda, and the higher Malacostraca. They present the exception to the constant number of segments in this class, there being eight abdominal segments, or twenty-one in all. A thin bivalve shell covers the greater part of the body; the head bears a pair of compound, stalked eyes, and the thoracic appendages are leaflike, resembling those of the Phyllopoda. The most common genus is Nebalia (Fig. 152), which is less than a centimeter long.

## SUBCLASS II. ARTHROSTRACA

The Arthrostraca (Gr. ἄρθρον, joint, and ὄστρακον, shell) possess the typical twenty segments of the Malacostraca, with a pair of appendages on each except the last. The first thoracic segment is fused with the head, sometimes the first two; but all the remaining segments of the body are distinct. The thoracic appendages, except the first pair, are organs of locomo-

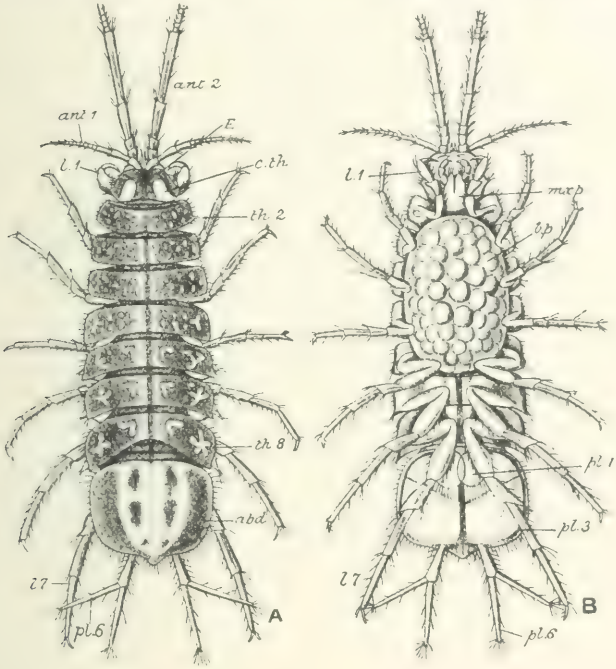



FIG. 153. *Asellus aquaticus*. A, dorsal aspect; B, ventral. *ant.1*, antennule; *ant.2*, antenna; *bp*, brood pouch; *c.th*, cephalothorax; *E*, eye; *l.1–l.7*, legs; *pl.1*, *pl.3*, *pl.6*, pleopods; *th.1–th.8*, free thoracic segments. (After Gerstaecker, from Parker and Haswell's Textbook.)

tion and consist of the endopodite only; the abdominal appendages are biramous. The eyes in this group are sessile. Two orders are commonly recognized.

### Order 1. Isopoda

The Isopoda (Gr. ἴσος, similar, and πούς, foot) are mostly marine; a few occur in fresh water and on the land. They are

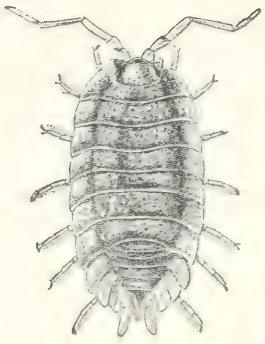


FIG. 154. *Porcellio scaber*, a wood louse, enlarged about two diameters. (From Shipley and MacBride's Zoölogy.)

readily distinguished from the second order of Arthrostraca by the general shape of the body, which is decidedly flattened dorsoventrally. The seven pairs of walking appendages on the thorax are all very much alike, and in the female some of them have special plates on the inner side, which serve to hold masses of eggs in place against the ventral wall of the body, where they remain during a considerable period of their development (Fig. 153). The abdominal appendages are more or less platelike and most of them function as gills. Most of the Isopoda are free-living, but some are more or less permanently parasitic on the skin and in the mouth of fishes;

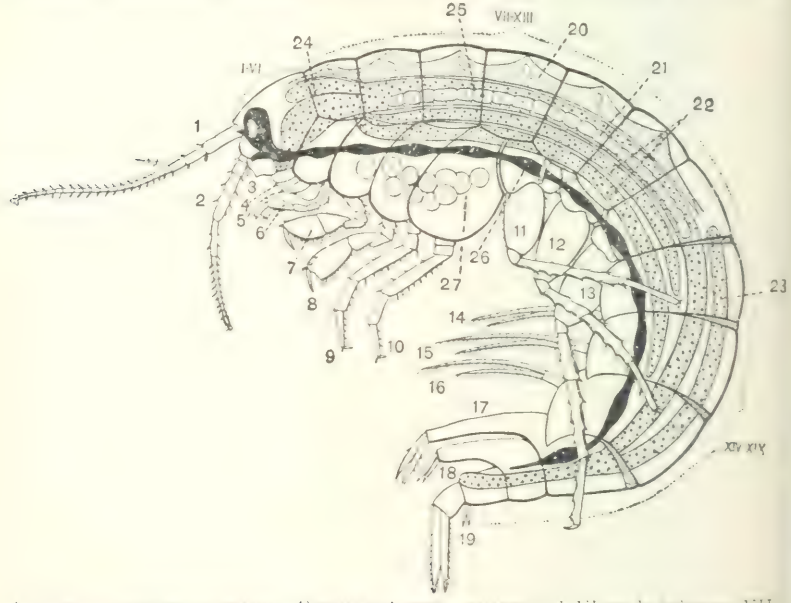



FIG. 153. [illegible] Female with eggs [illegible]. I-VI, cephalothorax; VII-XIII, free thoracic segments; XIV-XIX, the six abdominal segments. 1, anterior antenna; 2, posterior antenna; 3, mandible; 4, first maxilla; 5, second maxilla; 6, maxilliped; 7-13, thoracic legs; 14-16, three anterior abdominal legs for swimming; 17-19, three posterior abdominal legs for jumping; 20, heart with six pairs of ostia; 21, ovary; 22, hepatic diverticula; 23, posterior diverticulum of the alimentary canal; 24, median dorsal diverticulum; 25, [illegible]; 26, nervous system; 27 [illegible] on the coxæ of the second, third, and fourth thoracic legs. (After Sars, from Shipley and MacBride's Zoölogy.)

some live in the gill chambers of higher Crustacea, and in such cases the dwarf males often live attached to the female. The sexes are usually separate, but some parasites are hermaphroditic, and in one hermaphroditic genus the animals are males when young and females when they become older. The land Isopoda are represented by such animals as the wood-lice or sow bugs (Fig. 154), which are very common under logs or decaying wood.

## Order 2. Amphipoda

The Amphipoda (Gr. *ἀμφί*, on both sides, and *πούς*, foot) are chiefly marine, but include some fresh-water species, like the

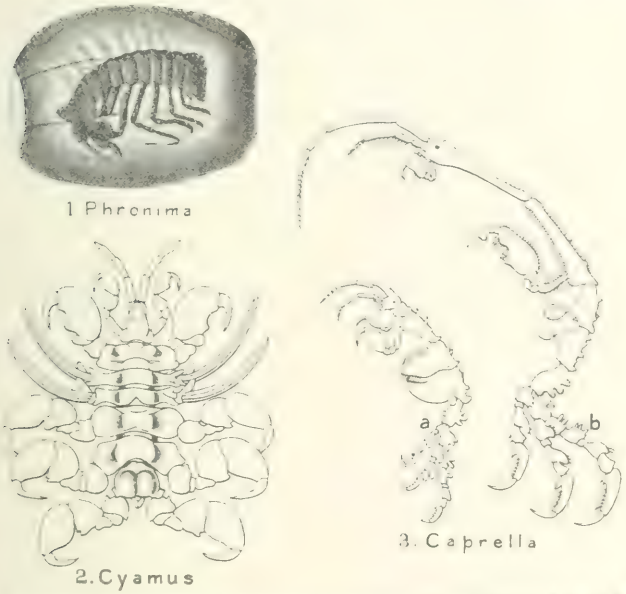



Fig. 156. Various **Amphipoda**. 3 **a**, male; **b**, female. (After Gerstaecker, and Peter and Westwood, from Parker and Haswell's Text-book.)

fresh-water shrimp, and some that may live on land, like the sand hoppers or beach fleas (Fig. 155). One genus is parasitic on the skin of whales. In this order the body is compressed laterally instead of dorsoventrally as in the Isopoda. There is often more or less differentiation among the thoracic appendages. The majority of them usually bear soft processes which function

as gills; and in the female some of them are provided with thin chitinous plates on the inner side, which by overlapping form a brood pouch for the developing young, very much as in the preceding order. Of the six pairs of biramous abdominal appendages usually present, the three anterior pairs are used for swimming, and the three posterior are used in jumping. In some genera the abdomen is very much reduced and appendages are wanting, as in the bizarre Caprella (Fig. 156), which is commonly found crawling amongst hydroids.

## SUBCLASS III. THORACOSTRACA

The Thoracostraca (Gr. *θώραξ*, breastplate, and *ὄστρακον*, shell) are readily distinguished from the Arthrostraca by two striking differences. We noted in the Arthrostraca that only the first thoracic segment was fused with the head and that the remaining seven were distinct. In the Thoracostraca, all or nearly all of the segments of the thorax fuse with the head, forming a more or less complete cephalothorax; and this entire region is then covered by a single piece of shell, the carapace, which also extends down over the sides of the body and covers the gills, when these are attached to the thoracic appendages, and thus forms a gill chamber. In the abdomen, the segments are distinct. The second point of difference lies in the eyes, which in the Arthrostraca are sessile, and in the Thoracostraca are situated at the free ends of rather long stalks. This group is divided into four orders.

### Order 1. Cumacea

The Cumacea (Gr. *κῦμα*, anything swollen, wavelike) present the one exception to the statement just made, that the eyes of the Thoracostraca are stalked; this is the only order in which they are sessile. The carapace covers only the first three or four thoracic segments; the remaining four or five are distinct. The Cumacea are marine and form a small order. A common genus is Diastylis (Fig. 157), about a centimeter in length.

## Order 2. Stomatopoda

The Stomatopoda (Gr. *στόμα*, mouth, and *πούς*, foot) again form a very small order; they are exclusively marine and live only in the warmer waters. They are Crustacea of some size

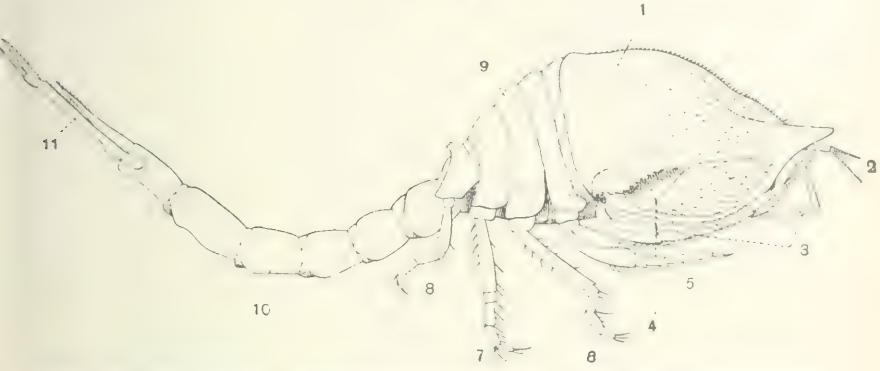



FIG. 157. *Unachis stygia*. Female enlarged six diameters. 1, carapace; 2, first antenna; 3, first leg; 4, gill borne on first maxilliped; 5, 6, 7, 8, second to fifth leg; 9, free portion of thorax; 10, abdomen; 11, appendage of last abdominal segment. (After Sars, from Shipley and MacBride's Zoölogy.)

and may attain a length of fifteen centimeters. One of the commonest representatives is Squilla (Fig. 158). The cephalothorax includes only the head and the first five thoracic segments, so that the carapace leaves three segments of the thorax uncovered, and these are distinct. The first five pairs of thoracic

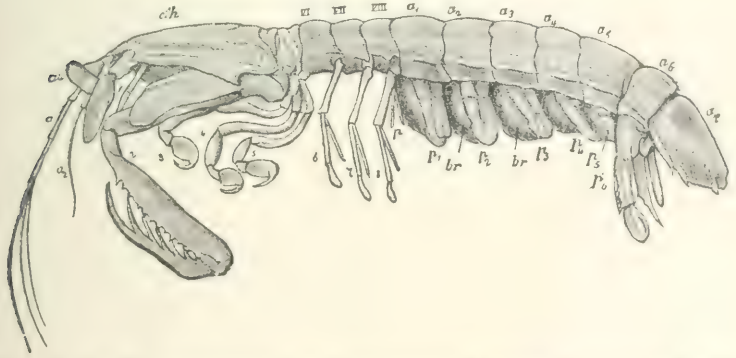



FIG. 158. *Squilla*. $a_1$, antennule; $a_2$, antenna; $a_3$-$a_7$, abdominal segments; *br*, gills; *cth*, cephalothorax; *p*, copulatory organ; $p_1$-$p_5$, pleopods; $p_6$, uropod; VI–VIII, thoracic segments; 1–8, thoracic appendages. (From Parker and Haswell's Text-book.)

appendages are mouth parts, and the more posterior of these are very large and strong; they consist of a single row of joints, while the remaining three pairs of thoracic appendages are biramous. The abdomen is strongly developed, and the six pairs of appendages are large, biramous, swimming organs; to the first five pairs of these gills are attached.

### Order 3. Schizopoda

The Schizopoda (Gr. *σχίζα*, cleft, and *πούς*, foot) are small marine Thoracostraca, rarely more than half a centimeter in length and often less. They are transparent, shrimplike, and derive their name from the eight pairs of thoracic appendages, which are all very much alike and biramous, hence "split-footed." Gills are sometimes present on the thoracic appendages. The carapace covers practically the whole thorax, though one or two of the posterior segments may remain distinct. The sixth abdominal segment has a pair of large appendages, which together with the seventh segment, or telson, form the flapper or tail fin, and on these appendages is found in some species the curiously placed ear or auditory vesicle. A common representation of this order is the genus Mysis (Fig. 150).

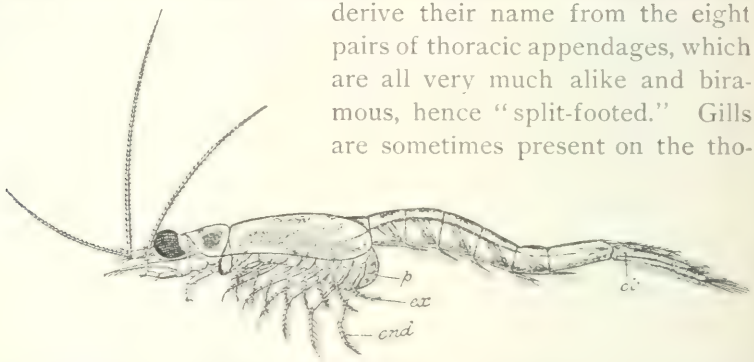



FIG. 159. *Mysis oculata*, enlarged. *end*, endopodite; *ex*, exopodite; *ot*, otocyst; *p*, brood pouch. (After Gerstaecker, from Parker and Haswell's Text-book.)

### Order 4. Decapoda

The Decapoda (Gr. *δέκα*, ten, and *πούς*, foot) include the largest and most highly developed Crustacea. The order receives its name from the five posterior pairs of appendages on the thorax, which are always well developed and employed for the most part for walking. In this group there is a complete

cephalothorax, consisting of a fusion of all the thoracic segments with the head, and the carapace forms a complete covering extending as far back as the abdomen and covering the gills on the sides of the body. The head bears the stalked, compound eyes and five pairs of appendages, — two pairs of antennæ, and three pairs of mouth parts. On the thorax are the usual eight pairs of appendages, of which the first three are biramous mouth parts and the succeeding five consist of endopodites only. The abdomen possesses the usual seven segments with six pairs of appendages, mostly biramous.

The gills are attached to the thoracic appendages, and lie in the gill chamber. In some crabs which live the greater part of

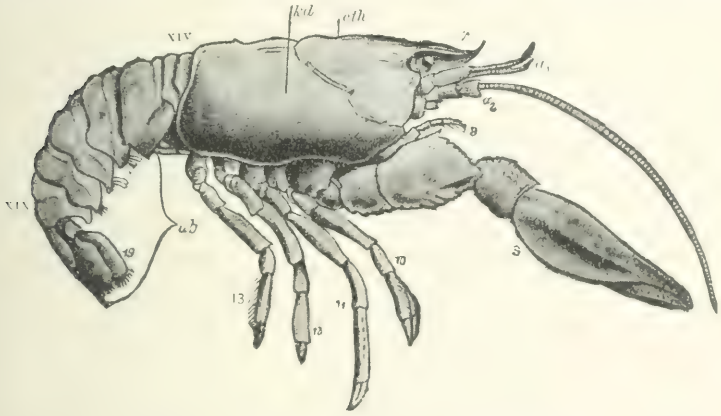



FIG. 160. *Astacus fluviatilis*, the fresh-water crayfish. Lateral aspect of male. $a_1$, antennule; $a_2$, antenna; *ab*, abdomen; *cth*, cephalothorax; *kd*, gill-cover; *r*, rostrum; 8, third maxilliped; 9–13, legs; 19, uropod; XIV, first abdominal segment; XIX, sixth abdominal segment. (From Lang's Comparative Anatomy.)

the time on land, this gill chamber is modified into a sort of pulmonary or lung chamber, so that the animal may use the air directly. The genital openings occur in the female at the base of the fifth thoracic appendage, and in the male at the base of the eighth; the first pair of abdominal appendages in the male is modified into a copulatory organ. The stomach is provided with strong, chitinous teeth for grinding up the food; the anus is on the ventral side of the telson. At the time of ecdysis, the animal crawls away into some obscure corner, where it is likely to be concealed from its enemies, and after cracking its shell, crawls

out. The body is then very soft, and the soft-shelled crabs of the epicureans are captured at just this time. The animal then

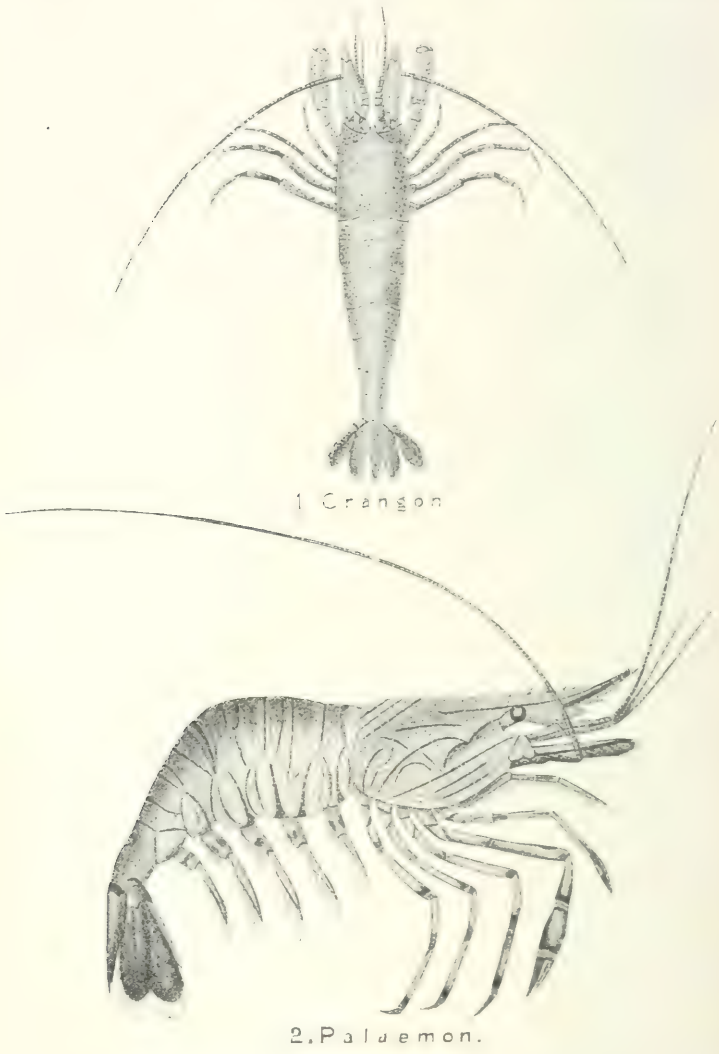



FIG. 161. *Crangon*, the shrimp, dorsal aspect, and *Palæmon*, the prawn, lateral aspect. (After Cuvier, from Parker and Haswell's Text-book.)

swells and the skin begins to calcify until it is as hard as the cast-off shell.

The Decapoda may be separated into two groups, the first including animals like the lobster in which the abdomen is strongly developed, and the second the crabs, in which the abdomen is very much reduced in size. The lobsters are marine Crustacea found in shallow water along the coasts of Europe and North America and are so extensively taken for food that there is danger of their extermination; from twenty to thirty million are said to be caught annually on the coasts of New England and Canada. A trap called a lobster-pot is used for taking them, — a semi-cylindrical structure of slats, which is baited with some decaying animal matter, as this forms the chief food of the lobster. When alive the animal is usually dark green in color and becomes red on boiling.

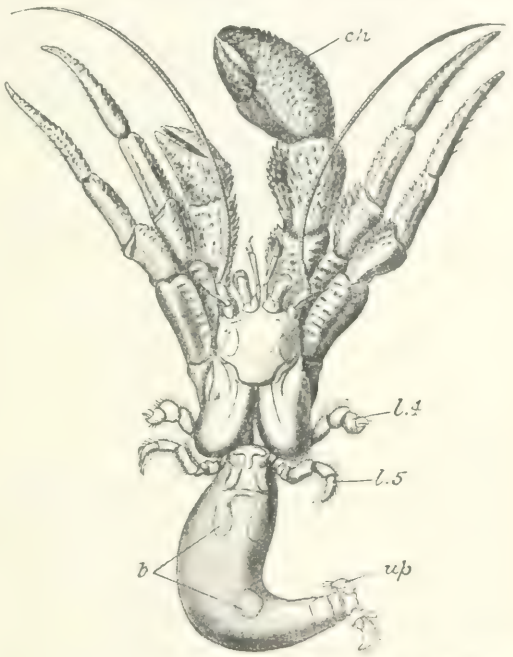



FIG. 162. *Pagurus bernhardus*, the hermit crab. ½ Europe. *cl*, chela of first right leg; *l.4*, *l.5*, fourth and fifth legs; *b*, abdominal torga; *up*, uropod. (After Boas, from Parker and Haswell's Manual.)

The lobster-like animals include the fresh and salt water crayfishes (Fig. 160), the prawns (Fig. 161), which have a soft shell, not calcified and with appendages for swimming instead of walking, the shrimps (Fig. 161) and the hermit crabs (Fig. 162), which live in the empty shells of snails. In these hermit crabs the abdomen is soft and has lost nearly all of its appendages, as they would be useless inside the snail shell, and the hard parts are confined to the cephalothorax; as the animal increases in size it seeks a larger shell.

The true crabs (Figs. 163 and 164) are mostly marine, though some occur in fresh water, some live on sandy beaches just above the water, while some in the tropics are essentially land

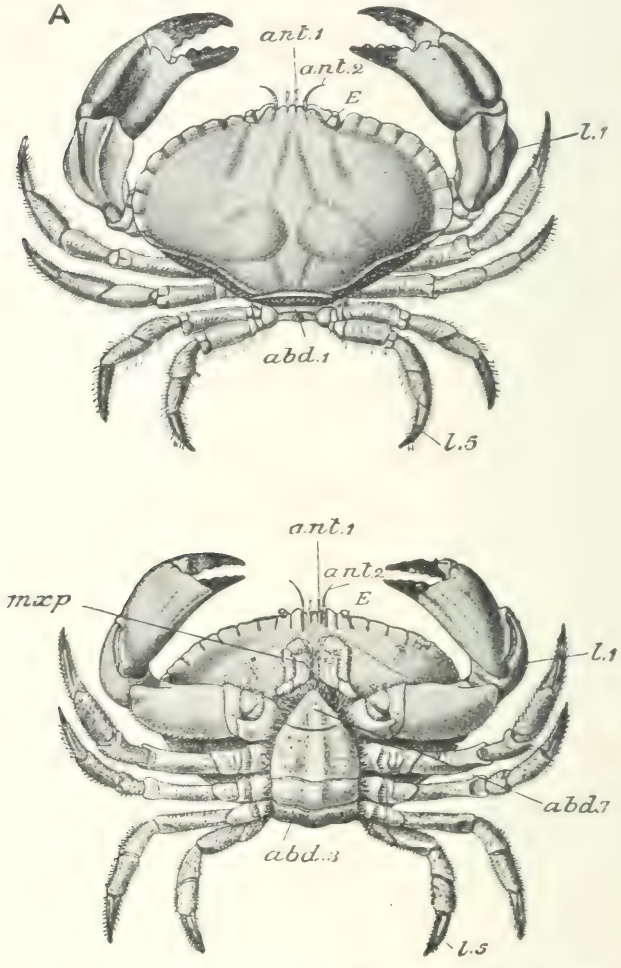



FIG. 163. *Cancer pagurus*. A, dorsal aspect; B, ventral. *ant.1*, antennule; *ant.2*, antenna; *abd.1*, 2, 3, abdominal segments; *E*, eye-stalk; *l.1*, *l.5*, legs; *mxp*, third maxilliped. (From Parker and Haswell's Manual.)

animals, going to the sea only during the breeding season, when they frequently migrate thither in very large numbers. The largest crab known is found in Japan; the body is about thirty centimeters in diameter, but the legs are so long that when

extended the animal may measure four or five meters across. Sponges are often found attached to the carapace of some crabs, and undoubtedly serve to conceal them from their enemies,

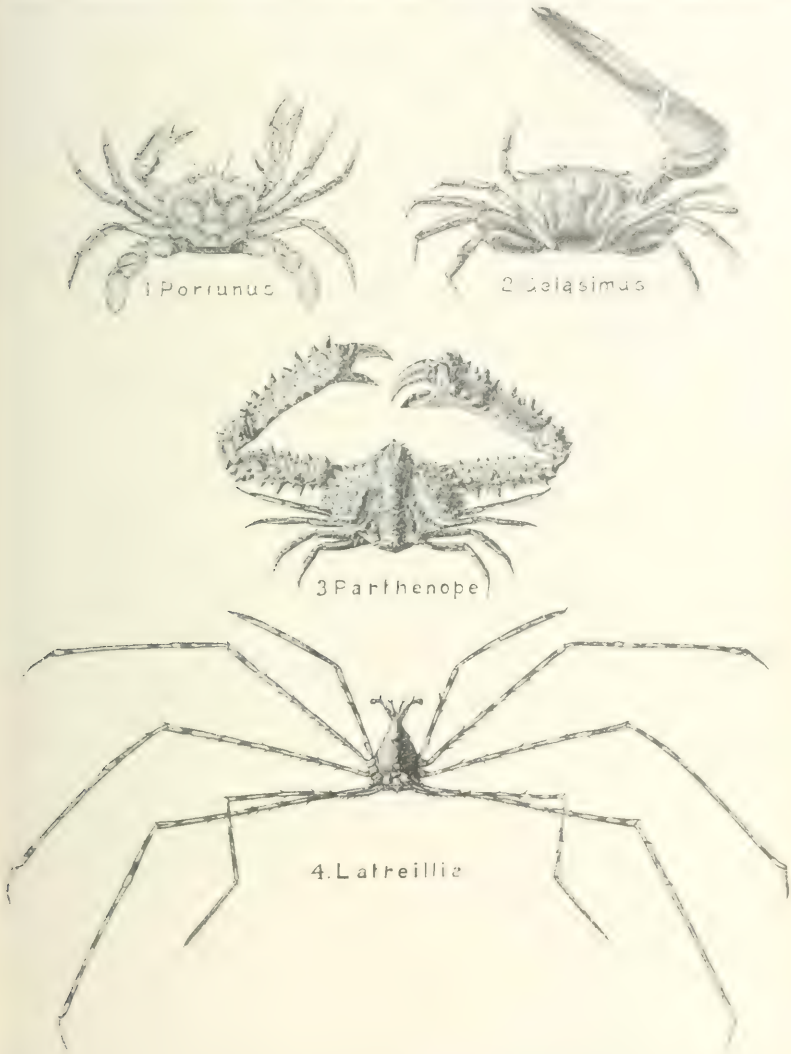



FIG. 164. Various crabs. (After Bell and de Haan, from Parker and Haswell's Text-book.)

while the sponge has the advantage of being carried about to fresh feeding grounds. The borrowed houses of the hermit crabs

are often more or less covered with hydroids or sea anemones (Figs. 47 and 61), which serve the same purpose and derive the same advantage. This superficial way of living together is often called commensalism.

The development of the Decapoda is attended by a considerable variety of larval types. In some fresh-water species there is no free-swimming larva, but the nauplius remains within the eggshell and is there metamorphosed into a form like the adult.

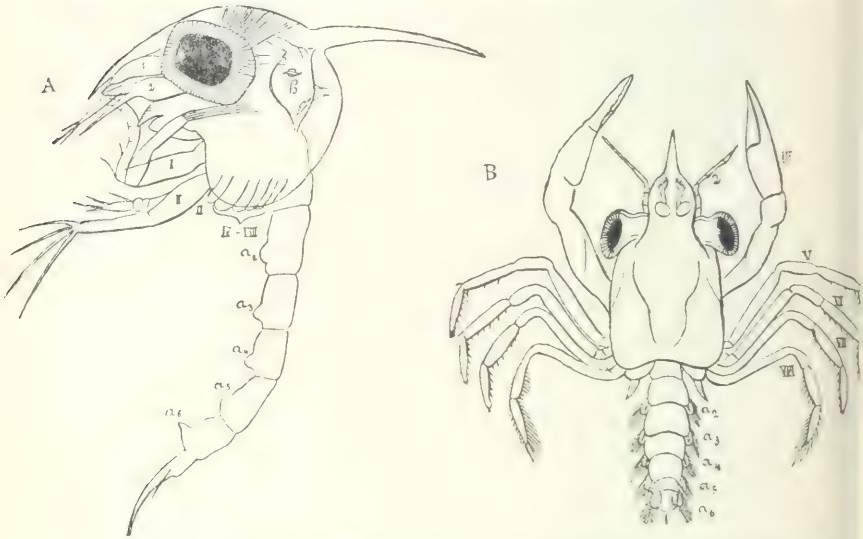



FIG. 165. Larvæ of crabs. A, zoëa stage of *Maja;* B, megalops stage of *Portunus*. $a_2$–$a_6$, abdominal segments; *h*, heart; *1*, antennule; *2*, antenna; I–VIII, thoracic appendages. (After Claus, from Parker and Haswell's Text-book.)

In some prawns the larva leaves the egg as a nauplius, just as in the Entomostraca. Then by successive moults or ecdyses it passes into a form called the zoëa larva (Fig. 165). This is succeeded by a stage resembling the adult Schizopoda and called the Mysis stage, in which it is provided with biramous thoracic appendages. This stage is followed by the adult form. In the crabs the nauplius remains in the egg membrane and the zoëa is the first free-swimming larva. It is succeeded by a stage called the megalops larva (Fig. 165), which in turn is metamorphosed into the form of the adult crab. In the lobster the only free-swimming larva is the Mysis stage, as the embryo passes through both the nauplius and the zoëa stages in the egg.

## Supplementary Order Xiphosura

The Xiphosura (Gr. *ξίφος*, sword, and *οὐρά*, tail), called commonly the king crabs or horseshoe crabs, constitute an order intermediate in a way between the Crustacea and the succeeding subtype, the Arachnida, so that it seems best to take it up at this point. There is only a single genus, Limulus (Fig. 166), with very few species, and it occurs in salt water on sandy shores along the eastern coast of the United States, on the West Indies, and on some of the East Indies. They grow to a considerable size, sometimes becoming some thirty centimeters broad and at least twice as long. The body consists of three parts: the horseshoe-shaped cephalothorax, convex on the dorsal side and concave beneath, the abdomen of fused segments, and the stiff, swordlike tail, which is probably to be regarded as a portion of the last segment of the abdomen.

FIG. 166. *Limulus polyphemus*, the horseshoe crab, adult female; actual length, forty-six centimeters. (Photographed from a dried specimen by the author.)

The cephalothorax bears the mouth on its ventral surface surrounded by six pairs of appendages; the first pair is small, the others are larger and serve as walking feet; antennæ are apparently absent entirely. At the posterior end of the cephalothorax is a seventh pair of appendages, regarded by some zoologists as belonging to the thorax and by others as constituting the first pair of abdominal appendages. This pair is broad and platelike, the two meeting on the median line of the body and forming a sort of cover — hence called the operculum — to the succeeding five pairs of abdominal appendages, which are also platelike

All these six pairs are regarded as biramous, thus being built on the plan of the typical crustacean appendage and showing a relationship to that group. The abdominal appendages bear, on their posterior surfaces, numerous delicate folds, which function as gills; these folds, arranged at right angles to the surface of the appendage, resemble the leaves of a book. At the posterior end of the abdomen on the ventral side is the anus. On the dorsal side of the cephalothorax are two simple eyes, symmetrically placed near the median line, and two compound eyes much farther apart. The sexes are separate and the development is interesting, since a larva is formed, resembling to some extent the adult, but without a tail and

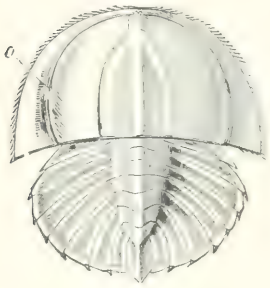



FIG. 167. *Limulus*. Embryo in the trilobite stage; enlarged. *e*, eye. (After Dohrn, from Claus and Sedgwick's Textbook.)

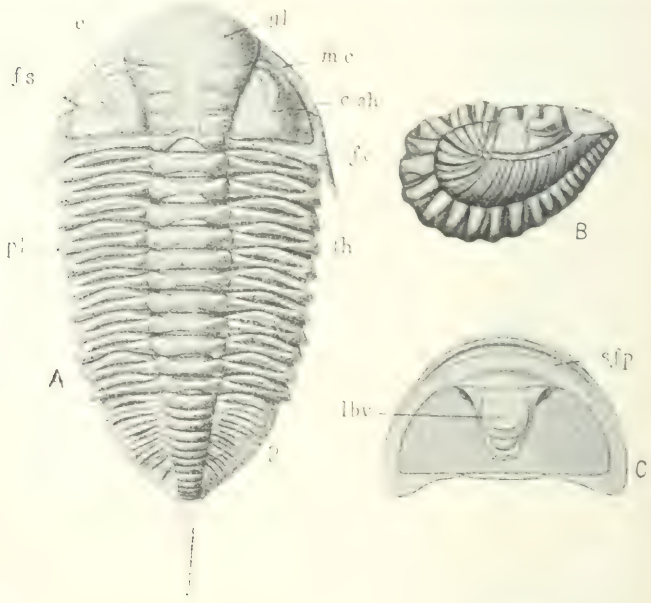



FIG. 168. A, *Dalmanites socialis*, dorsal aspect; B, the same rolled up, lateral aspect; C, ventral side of head of *Phacops fecundus*. *c.sh*, cephalic shield; *e*, eye; *f.c*, fixed cheek; *f.s*, frontal suture; *gl*, glabella; *lbv*, labrum; *m.c*, movable cheek; *p*, pygidium; *pl*, pleura; *s.f.p*, subfrontal plate; *th*, thorax. (After Gerstaecker, from Parker and Haswell's Textbook.)

with the abdomen consisting of distinctly separate segments (Fig. 167). This is known as the trilobite stage because of the resemblance to some of the class of extinct Crustacea, the Trilobitæ (Fig. 168) whose remains occur in the Palæozoic rocks. In these same formations are found the fossils of another class of Crustacea, the Gigantostraca (Fig. 169), which attained a length of over a meter, and show many points of resemblance to the adult Xiphosura, but differ chiefly in having a distinctly segmented abdomen.

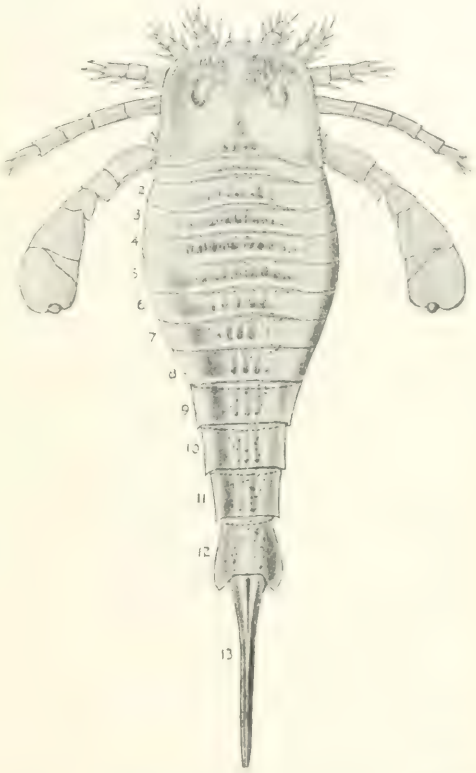



FIG. 169. *Eurypterus fischeri*, from the Silurian. (From Parker and Haswell's Text-book.)

## SUBTYPE II. ARACHNIDA

The Arachnida (Gr. *ἀράχνη*, spider) are readily distinguished from the preceding subtype by the organs of respiration, which are always adapted to breathing air directly, and from the succeeding subtype by the number of appendages present. This group is represented by the scorpions, spiders, mites, and similar animals, and is therefore essentially terrestrial. The body generally exhibits two regions, a cephalothorax and an abdomen, the former usually much the shorter. There are six pairs of appendages and all are attached to the cephalothorax; of these the first two pairs are modified for seizing food or carrying it to the mouth and therefore may be considered mouth parts; the remaining four pairs are walking legs. All the appendages

consist of a single row of segments. There is very great variation in the shape and structure of the abdomen, as we shall note under the different orders. The sexes are always separate.

The organs of respiration are of two kinds. In the one case they consist of chambers, the wall of which is thrown into a large number of parallel folds resembling the leaves of a book. In the leaves themselves are the blood vessels, and between the leaves the air circulates freely. The chamber opens to the outside by a slitlike opening, the stigma. Such respiratory organs

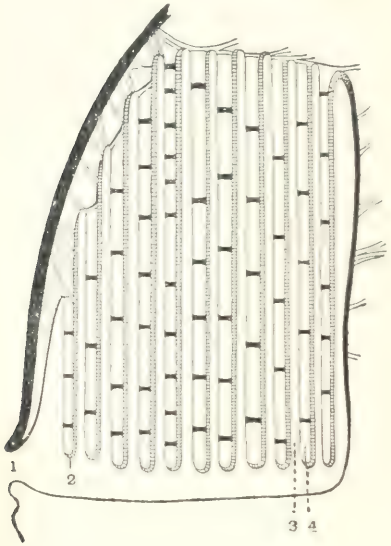



FIG. 170. Longitudinal section through the lung book of a spider. 1, external opening or stigma; 2, free edge of the pulmonary leaves; 3, space in which the air circulates; 4, space in which the blood circulates. (From Shipley and MacBride's Zoölogy.)

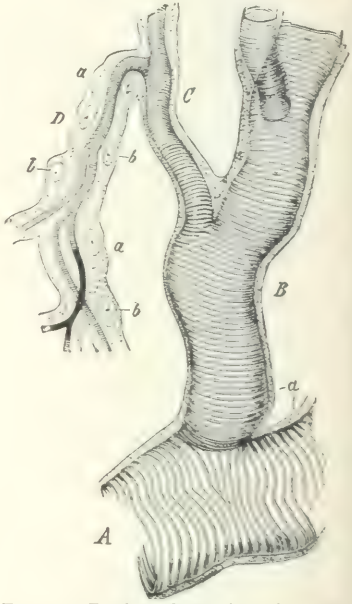



FIG. 171. Portion of a trachea of a caterpillar. *A*, main tube; *B*, *C*, *D*, branches; *a*, connective; *b*, nuclei. (From Parker and Haswell's Text-book.)

are called lung books (Fig. 170). They are arranged symmetrically, and there are never more than four pairs. In the other case the organs of respiration consist of richly ramifying tubes called tracheæ, closed at their inner ends and opening on the surface of the body by symmetrically arranged stigmata, of which there are never more than four pairs. These tubes (Fig. 171) are kept distended by a spirally wound, chitinous band, resembling a spring. This subtype is sometimes divided into two classes, the

Arthrogastres, in which the abdomen is segmented and including the first five orders given below, and the Sphærogastres, in which it is unsegmented, comprising the last two orders.

### Order 1. Scorpionida

The Scorpionida (Lat. *scorpio*, scorpion), or scorpions, are animals inhabiting warm countries, the largest species being confined to the tropics, where they attain a length of fifteen centimeters and are of a dark brown color. Most scorpions are much smaller, however, like our light brown Florida species, which is usually only six or seven centimeters long. They are nocturnal animals, living under stones and in holes or other dark places during the day and seeking their prey at night; they feed principally on spiders and insects, which they sting to death and

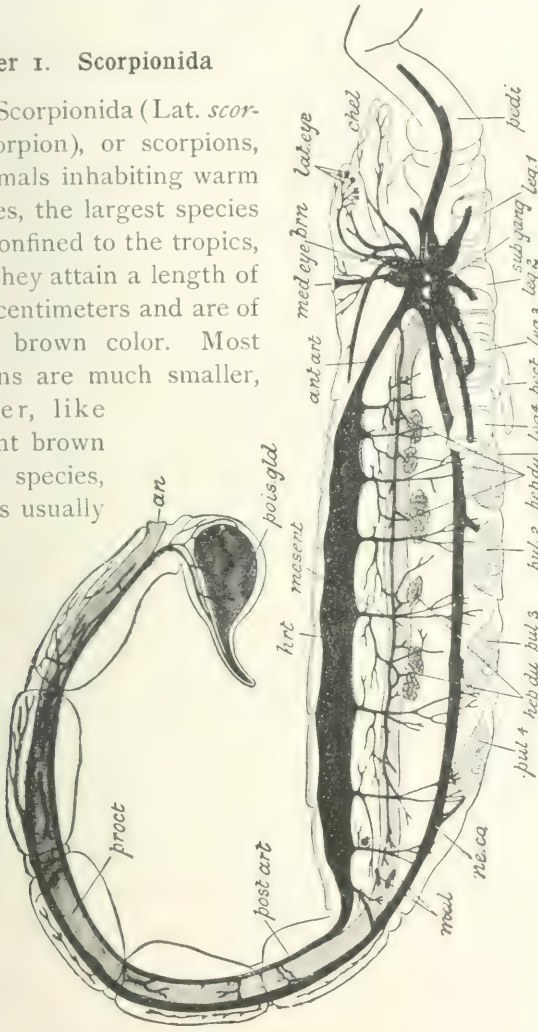



FIG. 152. Diagrammatic side view of the internal organs of a scorpion. *an*, anus; *ant. art*, anterior aorta; *bra*, brain; *chel*, chelæ; *hrt*, heart; *lat eye*, lateral eyes; *leg 1–4*, legs; *mod*, Malpighian tubes; *med eye*, median eyes; *mesent*, mesentery; *nerve cord*; *pedi*, pectines; *ped. pr*, pedipalp; *pois gld*, poison gland; *pul. art*, pulmonary artery; *pul. sac*, pulmonary sac; *sub. ya*, subyang; *tes*, testes. (After Parker and Haswell's Manual.)

then suck the fluids from the body. The cephalothorax is relatively short and bears the typical six pairs of appendages, the first pair very small, the second the largest of all, the others simple walking legs. On the dorsal side of the cephalothorax are from two to six pairs of eyes; usually one pair is large and situated near the median line, the others being more lateral in position.

The abdomen is very long, distinctly segmented, and divided into two parts, the large, rounded preabdomen consisting of seven segments, and the more slender postabdomen consisting of six segments; this latter portion is commonly called the tail. On the ventral side of the first abdominal segment is the genital opening, provided in the male with a double penis. Just posterior to the genital opening is a pair of comblike appendages, the pectines, probably sensory in function. Then in each of the four succeeding segments, the third, fourth, fifth, and sixth, is a pair of slitlike stigmata, which connect with the four pairs of lung books or respiratory chambers.

The segments of the postabdomen are all very much alike except the last. This is provided with a sharp spine at whose tip is the opening of a pair of poison glands situated within. The anus is at the base of the last segment, just at the posterior end of the fifth, so that the postabdomen may be regarded as consisting of five segments, with the poison glands contained in an appendage of the fifth segment (Fig. 172). When walking, the postabdomen is carried curved upward over the dorsal side of the body and then is suddenly lowered when the animal wishes to strike anything. The poison kills small animals instantly; the sting of the largest species may possibly be fatal to man, at any rate it produces a very unpleasant illness. The scorpions are viviparous, the young being born in a condition differing but little from the adult except in size.

### Order 2. Pseudoscorpionida

The Pseudoscorpionida (Gr. *ψευδής*, false, and *σκορπίος*, scorpion) are minute Arachnida, often less than two millimeters in length, which live under the bark of trees and in old books, and hence are sometimes called book scorpions (Fig. 173). The

body is greatly flattened dorsoventrally. They are strikingly like the true scorpions in many respects, but there is no narrow postabdomen and no poison spine. The cephalothorax is much the same as in scorpions. The abdomen is oval and consists of eleven segments. Near the genital opening on the second abdominal segment are spinning glands, which secrete fine, silky threads to attach the eggs to the abdominal wall; these resemble the spinning glands found in spiders. There are only two pairs of stigmata, on the first and second abdominal segments, and these connect, not with lung books, but with tracheæ.

FIG. 173. *Chelifer* [illegible] a book scorpion. 2–6, second to sixth pairs of appendages. (From Lang's Comparative Anatomy.)

### Order 3. Pedipalpi

The Pedipalpi (Lat. *pes*, foot, and *palpus*, feeler) are commonly called the scorpion spiders (Fig. 174). They are tropical animals and attain a considerable size. Of the six pairs of appendages on the unsegmented cephalothorax, the first pair is small and said to be poisonous, the third pair is extremely long and slender. The abdomen is flattened and consists of eleven or twelve

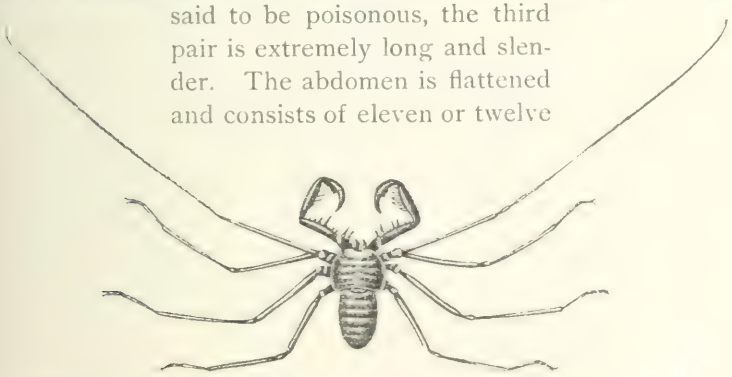


FIG. 174. *Phrynus*, a scorpion spider. (From Cuvier's Animal Kingdom.)

segments. It is round in outline in some species, in others the three posterior segments are very narrow, recalling the post abdomen of the scorpions, and the last segment is provided with a long lash or filament; hence these are often called the whip

scorpions. The Pedipalpi breathe by means of two pairs of lung books opening on the first and second abdominal segments.

### Order 4. Solpugida

The Solpugida (Lat. *solpuga*, a poisonous ant) are nocturnal animals, found in warm, sandy localities in Europe and America.

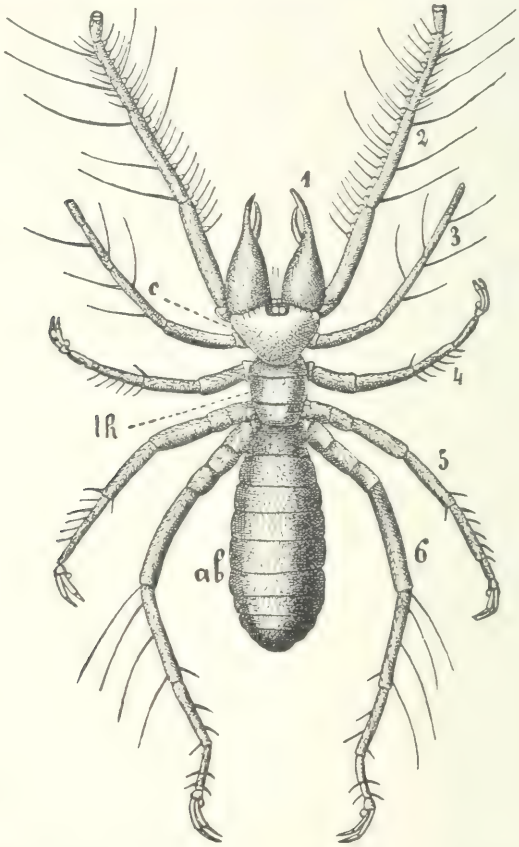



FIG. 175. *Galeodes desertorum*. ×, natural size. *ab*, abdomen; *c*, head; *th*, thorax; 1–6 the six pairs of appendages; 1, chelicerae; 2, pedipalpi. (After Dufour, from Parker and Haswell's Text-book.)

They are said to be poisonous, though no poison glands have been found. They differ from all other Arachnida in having the head and thorax distinct and the latter divided into three

segments. The abdomen possesses nine or ten segments. There are three pairs of appendages attached to the head and three to the thorax. The respiratory organs consist of tracheæ which open by means of three pairs of stigmata, one pair on the ventral side of the third thoracic segment, the other two on the second and third abdominal segments. Only two genera are known in this order (Fig. 175).

### Order 5. Phalangida

The Phalangida (Gr. *φαλάγγιον*, spider) are commonly called harvest men or daddy-long-legs (Fig. 176), and have an unseg-

FIG. 176. *Oligolophus spinosus*, a harvest man or daddy-long-legs; adult male, enlarged about two diameters. 1, cheliceræ; 2, pedipalpi; 3, 4, 5, 6, legs. (After Shipley and MacBride.)

mented cephalothorax, a swollen abdomen of six segments, and four very long legs. They are harmless little animals, avoiding

the daylight, and feed on small insects. Though resembling spiders somewhat, they differ most strikingly in having no spinning glands and in the method of respiration, which here is by means of the tracheæ, opening usually by only a single pair of stigmata on the first abdominal segment.

### Order 6. Araneida

The Araneida (Lat. *araneus*, spider), or spiders, constitute a large group readily distinguished from the other orders of Arachnida. There is an unsegmented cephalothorax and an unsegmented, rounded abdomen, the two parts being joined by

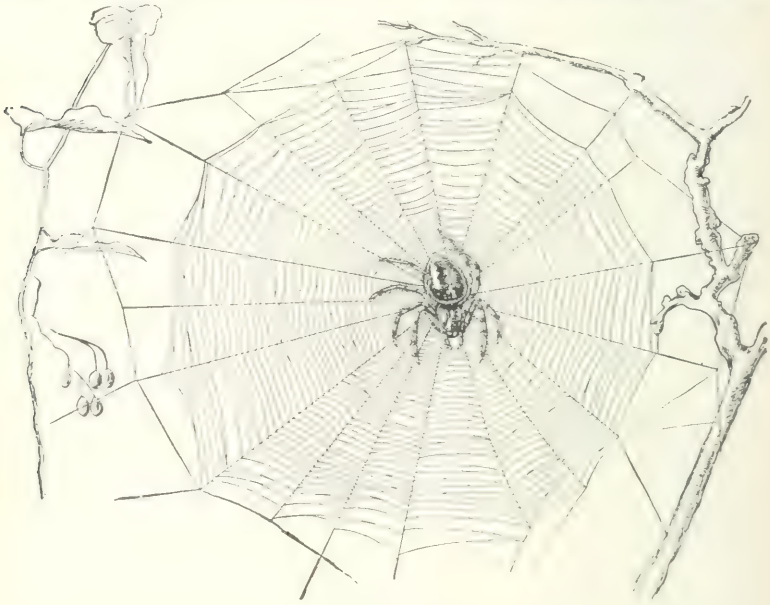


FIG. 177. *Epeira diadema*, the garden spider, on its web. (After Blanchard, from Shipley and MacBride's Zoölogy.)

a very slender stalk. The first pair of appendages is provided with poison glands; the poison of some of the larger spiders, such as the tarantula, produces serious, if not fatal, results in man. On the dorsal side of the head are from three to four pairs of eyes, very variously arranged in different genera. The spiders may be divided into two groups according to the method

of respiration. In the one there are two pairs of lung books, opening by as many stigmata on the anterior ventral portion of the abdomen. In the other there are two pairs of lung books and two pairs of tracheæ.

One of the most characteristic structures of the spiders is the spinning glands, which occur in large numbers in the posterior part of the abdomen. They open to the outside at the tips of little elevations, or papillæ, just anterior to the anus. There are from two to three pairs of these papillæ, or spinnerets, and at the tip of each is a number of very minute pores through which the viscid, fluid secretion of the glands is forced; it hardens on coming in contact with the air into a silklike thread of exquisite fineness. The size of the thread can be regulated by the number of spinning glands which it brings into play, but the coarsest spider-thread is finer than the finest thread of the silkworm's cocoon. These threads are used by spiders for various purposes. With them some construct the delicate webs (Fig. 177) with which they entangle their insect prey. Others build tubes for themselves out of these threads, in which they live. The trapdoor spider builds a home for itself in the ground or in a wall (Fig. 178), lines the chamber with this finest silk, and makes a hinged door to cover the opening, lining this in the same way. Most spiders lower themselves to the ground by secreting a thread as they fall, and many build cocoons about their eggs, in which the young develop.

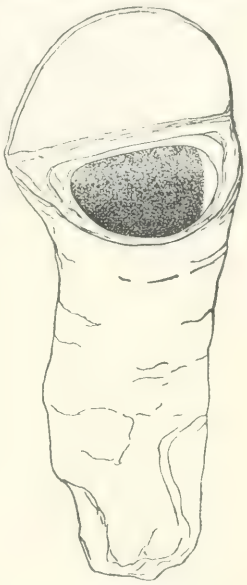


FIG. 178. Nest of a trapdoor spider, showing the semicircular lid raised. (Drawn from specimen by the author.)

The common garden spider, Epeira (Fig. 177), builds a very effective snare for insects. It fastens a series of threads from point to point across an open space, all the threads crossing each other at the same point. Next it starts at the center and lays a spiral thread over these radii for a considerable distance. Then going to the margin it begins a second spiral with a viscid thread running inward toward the center. This it fastens

securely on each radial thread and continues it to the center, biting away the first spiral as it advances.

One of the largest spiders is the tarantula, common in the tropics and in some of our Western states; with legs expanded it is sometimes fifteen centimeters in diameter; it is brownish in color, covered with hairs, and with its very long legs is a most repulsive-looking animal. The bird spider of tropical South America is another huge hairy spider, which sometimes attacks and kills small birds and mice. In all spiders the female is generally much larger and stronger than the male, while the latter is generally marked with much brighter colors than his mate. The two sexes do not generally live happily together, as the males are in constant danger of being killed by the females; sometimes they are found in the same web, sometimes on adjacent webs, but generally farther apart. Nearly all the spiders are land animals, but some live a good part of the time in fresh water; there they breathe by means of bubbles of air which adhere to the surface of the body when they go under water.

FIG. 179. *Demodex folliculorum*, a mite parasitic in hair follicles; greatly enlarged. *Kt*, pedipalps. (After Méguin from Claus and Sedgwick's Text-book.)

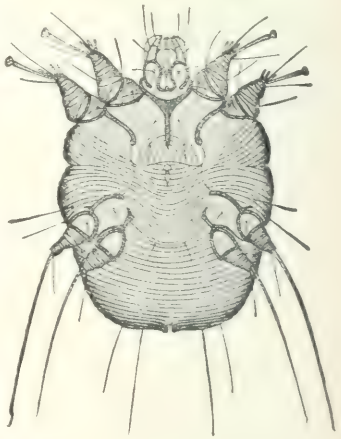


FIG. 180. *Sarcoptes scabiæi*, the itch mite. (After Leuckart, from Parker and Haswell's Manual.)

## Order 7. Acarina

The Acarina (Lat. *acarus*, mite), the ticks and mites, are minute Arachnida living on organic matter on land, or in fresh or salt water, or as parasites on plants or animals. There is no evidence of segmentation in the body,—head, thorax, and abdomen being fused into one mass. There are six pairs of appendages, — two pairs are mouth parts, and four pairs are legs;

the mouth parts are modified according to the life habits of the animal into organs for biting or piercing and sucking. The respiratory organs are tracheæ opening by a pair of stigmata, but in the water mites and some parasites there are no special organs of respiration, — in such cases respiration probably takes place through the skin. There is one mite that lives in the hair follicles of domestic animals, such as the cat, dog, cow, horse, and sheep, and many also occur in man; this genus has a greatly elongated, vermiform body (Fig. 179). The itch mites (Fig. 180) live in or upon the skin of the higher animals and produce the diseases known as the itch and the mange. Cheese mites occur on animal and vegetable matter. Others live as parasites on beetles, water insects, and birds. The ticks (Fig. 181) may be regarded as blood-sucking mites; they live in forests, and the females crawl on to man and other Mammalia, sucking the blood until they become greatly swollen; they are excessively annoying in the tropics, where they attain a considerable size.

FIG. 181. *Dermacentor variabilis*, the common dog tick or wood tick of the United States. Natural size, about five millimeters long. (Drawn from a preserved specimen.)

We come now to three orders whose systematic position is doubtful; as they may possibly have some relationship to the Arachnida, it is convenient to take them up at this point without assigning them a definite position in the scheme of classification.

### Supplementary Order Linguatulida

The Linguatulida (Lat. *linguatulus*, tongued), sometimes called the Pentastomida (Gr. πεντάστομος, five-mouthed), are elongated, vermiform animals, which are marked externally by a large number of rings; these, however, do not indicate segmentation. The adult individuals live as parasites in the nasal and some adjacent cavities of some of the higher animals, such as the fox, wolf, dog, tiger, lion, and exceptionally in man. The animal is very degenerate in structure. The mouth is near the anterior end of

the body, the anus at the posterior. There are two chitinous hooks on each side of the mouth, but no appendages. The sexes are separate; the male genital opening is just posterior to the mouth, the female is near the anus. In one species, *Pentastomum tænioides* (Fig. 182), the female is about eight centimeters long, the male only two centimeters.

The life history of these parasites is somewhat complicated, and two hosts are necessary for their development. The embryos pass from the nasal chambers of the hosts mentioned above, and getting on grass or other plants, are eaten by such animals as hares and rabbits, in which they develop into larvæ, provided with two pairs of appendages. These larvæ occur generally in the liver; one species has been found in the liver of negroes in Africa. When the host of these larvæ is eaten by carnivorous animals, they develop into the mature state in the nasal chamber. For some time these animals were classified with the worms, but the presence of the appendages in the larva is considered as relating them to the Arachnida.

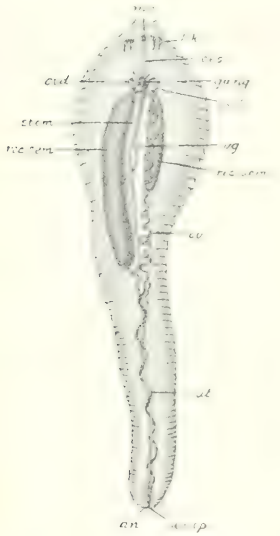


FIG. 182. *Pentastomum tænioides*. Young female; highly magnified. *an*, anus; *gang*, ganglion; *hks*, hooks; *mo*, mouth; *oes*, œsophagus; *ov*, ovary; *ovd*, oviduct; *rec.sem*, receptaculum seminis; *sex.ap*, sexual aperture; *stom*, stomach; *ut*, uterus. (After Leuckart, from Parker and Haswell's Text-book.)

### Supplementary Order Pycnogonida

The Pycnogonida (Gr. πυκνός, thick, and γόνυ, knee), sometimes called the sea spiders (Fig. 183), are exclusively marine, some living amongst seaweeds and hydroids along the shore, others at great depths; some are only a millimeter in diameter, some deep-sea species are over sixty centimeters in diameter. The body, which is always small, consists of a cephalothorax and abdomen. The anterior portion of the cephalothorax is unsegmented; the posterior part consists of three segments, to the last of which the very rudimentary, unsegmented abdomen is attached. The anterior end

of the body is extended into a proboscis with the mouth at its tip. Posterior to the proboscis on the dorsal side of the cephalothorax are two pairs of eyes. All the appendages consist of a single row of joints; the two anterior pairs correspond to the mouth parts of the Arachnida; the third pair, sometimes absent in the female, is slender and used for carrying the eggs; the remaining four pairs are very long, walking legs; thus there

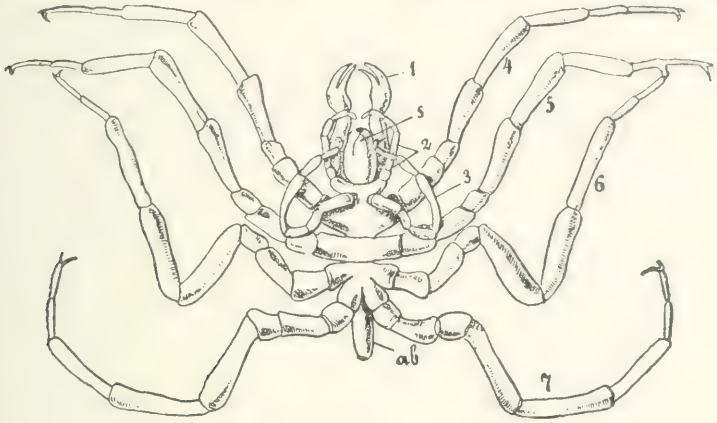



FIG. 183. *Nymphon hispidium.* *ab*, abdomen; *s*, proboscis; 1–7, appendages. (After Hoek, from Parker and Haswell's Text-book.)

are seven pairs in all. The sexes are separate and there is a larval stage in the development. These animals were formerly classified with the Crustacea, but it is now believed that they show a closer relationship to the Arachnida. There are no special organs of respiration.

### Supplementary Order Tardigrada

The Tardigrada (Lat. *tardus*, slow, and *gradus*, walk), the water bears or bear animalcules, are minute animals, not over one millimeter in length, which occur chiefly in fresh water or in moss, damp earth, or even along the sea shore. They have four pairs of short, stumpy appendages terminating in hooks, which they use for walking. The body is unsegmented and not highly developed. The surface is covered with a thin, chitinous cuticula, which is cast off from time to time, and within which the eggs develop; the sexes are separate. There are no special

organs of respiration, but the group is believed to be more closely related to the Arachnida than to any other. The principal genus is Macrobiotus (Fig. 184).

## SUBTYPE III. TRACHEATA

The Tracheata (Lat. *trachea*, air tube) in the adult condition breathe exclusively by means of tubes or tracheæ, which open to the outside by the symmetrically placed stigmata. The structure of the tracheæ is the same as that already described for some of the Arachnida. Thus these animals breathe air directly and are essentially land or air inhabitants, though some can remain under water for a considerable time. The body is, with one exception, distinctly segmented, and the appendages are never biramous, but consist of a single row of segments. There is always a single pair of appendages anterior to the mouth; these are the antennæ and are sensory in function. In the Tracheata the sexes are always distinct. The group is divided into three classes.

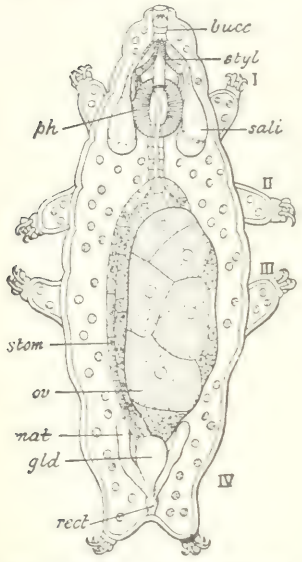



FIG. 184. *Macrobiotus [illegible]*, a bear animalcule; greatly enlarged. *bucc*, buccal cavity; *gld*, accessory gland; *mal*, Malpighian tube; *ov*, ovary; *rct*, rectum; *salı*, salivary glands; *stom*, stomach; *tes*, testis. (After Greef and Plate, from Parker and Haswell's Text-book.)

### CLASS I. PROTRACHEATA

The Protracheata (Lat. *pro*, before, and *trachcatus*, provided with tracheæ), or Onychophora (Gr. *ὄνυξ*, claw, and *φορέω*, to bear), are represented by a single genus, Peripatus (Fig. 185), which forms to a certain extent a connecting link between the Annelida and the

FIG. 185. *Peripatus capensis*. Lateral aspect. (From Parker and Haswell's Manual.)

Arthropoda. They are little, wormlike animals, commonly from five to six centimeters long, terrestrial, living in damp places under decaying wood or beneath stones, and are nocturnal in their habits. The body is not segmented, but the surface is transversely wrinkled, and there are many pairs of short, stumpy legs, externally ringed but not jointed, and each terminating in a pair of chitinous claws. The head bears a pair of antennæ, a pair of eyes, two jaws, and two papillæ, one on each side of the mouth. The anus is at the posterior end of the body. The respiration is by means of tracheæ, which open on the surface of the body by stigmata, which are very variously arranged in the different species. Thus by reason of their respiratory organs these animals are undoubted Tracheata. The excretory organs, on the other hand, are typical nephridia, such as occur in the Annelida, and thus demonstrate a relationship to these worms (Fig. 186). Peripatus is widely distributed and has been found in Africa, South America, the West Indies, New Zealand, and Australia.

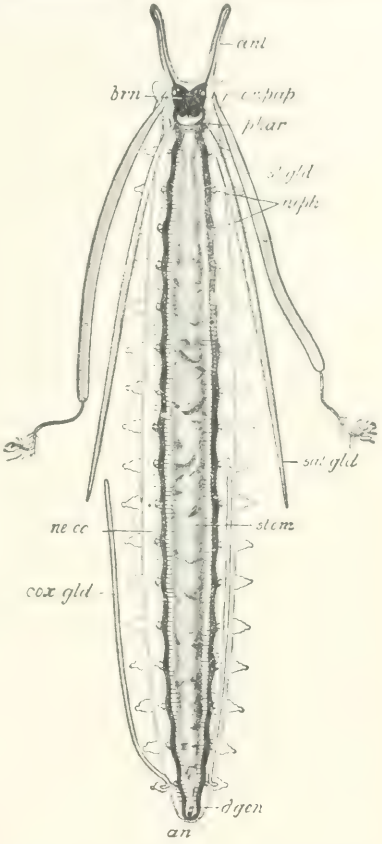



FIG. 186. *Peripatus.* Dorsal view of internal organs dissected. *an*, anus; *ant*, antennæ; *brn*, brain; *cox.gld*, coxal gland of the seventeenth leg; ♂ *gen*, male genital aperture; *ne.co*, nerve cord; *neph*, nephridia; *phar*, pharynx; *sal.gld*, salivary gland; *sl.gld*, slime gland; *stom*, stomach. (From Parker and Haswell's Manual.)

## CLASS II. MYRIAPODA

The Myriapoda (Gr. *μυρίος*, countless, and *πούς*, foot) are Tracheata possessing an elongated body, sometimes flattened

dorsoventrally, sometimes circular in cross section. There is a head made up of several fused segments, succeeded by a large number of distinct segments, essentially all alike, and each, with the occasional exception of the last, bearing one or two pairs of jointed appendages, each of which terminates in a claw. The head bears two many-jointed antennæ, several pairs of eyes, and from two to three pairs of mouth parts. The most anterior pair of mouth parts is usually very strongly developed and called the mandibles; the succeeding pairs are known as the first and second maxillæ. The anus is terminal. The stigmata are few in some cases, but usually there is a pair to each segment of the body. The eggs are deposited in the earth and often develop into a larva, which has only a few segments and fewer pairs of appendages; it moults repeatedly, gradually increasing the number of segments and of appendages. The Myriapoda are commonly divided into two orders, though two others, each comprising a single genus, are often recognized.

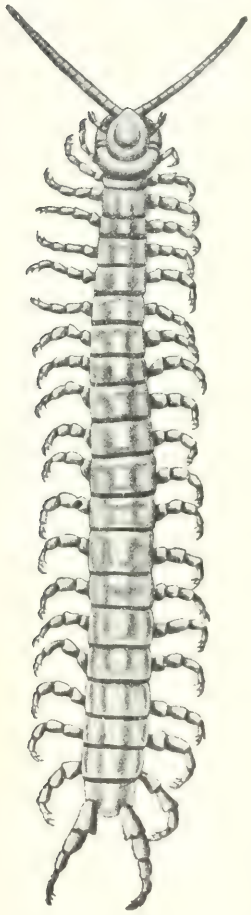


FIG. 187. *Scolopendra*, a centipede. (From Cuvier's Animal Kingdom.)

### Order 1. Chilopoda

The Chilopoda (Gr. χεῖλος, lip, and πούς, foot) are commonly called centipedes (Fig. 187), and have the body distinctly flattened dorsoventrally. They vary greatly in size, in the tropics sometimes attaining a length of twenty-five centimeters or even more. The antennæ have at least twelve joints and in some species are as long as the whole body. There are three pairs of mouth parts and on each segment of the trunk — there are sometimes over a hundred segments — a single pair of appendages of seven joints. The first pair of trunk appendages, just posterior to the mouth, is modified into two

strong, clawlike organs, called the maxillipeds, and at the tip of the claws is the opening of a poison gland. With these claws the largest tropical species can inflict wounds which are dangerous even to man. In some genera the embryos are essentially like the adult; in others there is a larva and metamorphosis. The centipedes are carnivorous.

### Order 2. Diplopoda

The Diplopoda (Gr. *διπλόs*, double, and *πούs*, foot) comprise the millipedes (Fig. 188), — sometimes called galleyworms, — whose body is nearly cylindrical, and provided with a relatively hard chitinous cuticula. Like the centipedes, they exhibit great variation in size, and in the tropics are found twelve or more centimeters long. The antennæ are short, having only seven segments. There are only two pairs of mouth parts, the mandi-

FIG. 188. *Iulus terrestris*, a "wire worm," enlarged about three and a half diameters. 1, antenna; 2, eye; 3, legs; 4, opening of gland. (From Shipley and MacBride's Zoölogy.)

bles and the first maxillæ. The first four or five trunk segments bear each a single pair of short appendages, attached near the median ventral line. The succeeding segments, with the exception of a few at the posterior end of the body, are really double segments, two being fused into one, so each bears two pairs of appendages. There are thus often over two hundred pairs of legs on one animal. There are no maxillipeds or poison glands, as in the centipedes; the millipedes are entirely harmless, and feed usually on decaying vegetable matter, sometimes on living plants. When disturbed they often roll up into a ball or spiral, thus protecting the softer ventral side of the body. The embryos develop into larvæ with only three pairs of legs, which by successive moults metamorphose into the adult.

## CLASS III. HEXAPODA OR INSECTA

The Hexapoda (Gr. ἕξ, six, and πούς, foot), or Insecta (Lat. *insectum*, cut up), comprise almost as many species as all the other groups of animals taken together. They vary in size from microscopic individuals to the huge butterflies and moths and beetles, and are of universal distribution. The air is the natural habitat of most insects; but some live on the ground, a few are parasites, and a few live on the surface of the water, fresh or salt, while the larvæ of insects, in addition to these habitats, may live in the earth or under water. But, notwithstanding this great diversity in size and mode of life, there is a remarkable uniformity in the characteristics which distinguish this class.

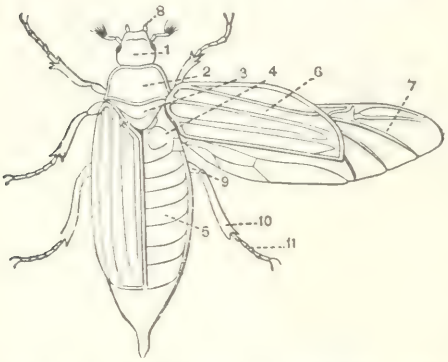



FIG. 189. *Melolontha vulgaris*, a cockchafer. Male, seen from above and slightly enlarged. 1, head, stretched forward; 2, prothorax; 3, mesothorax; 4, metathorax; 5, abdomen; 6, anterior wing, elytron, of right side, turned forward; 7, posterior wing of right side expanded; 8, maxillary palps; 9, femur of third right leg; 10, tibia of same; 11, tarsus of same. (After Vogt and Yung, from Shipley and MacBride's Zoölogy.)

The body is clearly divided into three regions, the head, thorax, and abdomen (Fig. 189). The head is unsegmented, but consists of at least four fused segments; it is provided with a firm chitinous covering and usually bears a pair of large compound eyes, often with simple eyes in addition, and four pairs of appendages; these consist of the many-jointed antennæ, and three pairs of mouth parts, which bear the same names as the corresponding organs in the Myriapoda, — mandibles, first maxillæ, and second maxillæ (Fig. 190). There is very great variation in form in these mouth parts, as they perform such a great diversity of functions in different insects, such as biting, gnawing, piercing, and sucking.

The thorax is always composed of three separate segments, called the prothorax, mesothorax, and metathorax, and each segment bears a pair of uniramous, jointed appendages on its ventral

surface; hence the name, Hexapoda, for this class. These appendages consist typically of five segments of different lengths, and the fifth or distal segment consists of from three to five very short segments. Here, as in the mouth parts, the structure varies with the function of the appendage, whether it be for walking, running, burrowing, jumping, climbing, or other purposes (Fig. 191). Attached to the dorsal side of the thorax there are typically two pairs of wings, the anterior pair on the mesothorax, the posterior pair on the metathorax; and the shape, size, and texture of these wings vary much.

The abdomen is likewise segmented, consisting typically of nine or ten metameres. The anus is at the posterior end of the abdomen, and just anterior to it is the usually single genital opening. The stigmata are generally numerous: they are absent on the head; there are at most two pairs on the thorax; on the abdomen they lie at the lateral boundaries of most of the segments. Of the internal structure of the insects (Fig. 192) we may simply note the high degree of development of the nervous system in many cases; the brain is a large and complicated structure, and the ventral nerve cord, while in some groups possessing ganglionic enlargements in each segment, in the more highly organized insects has these ganglia more or less approximated into a large mass in the thorax.

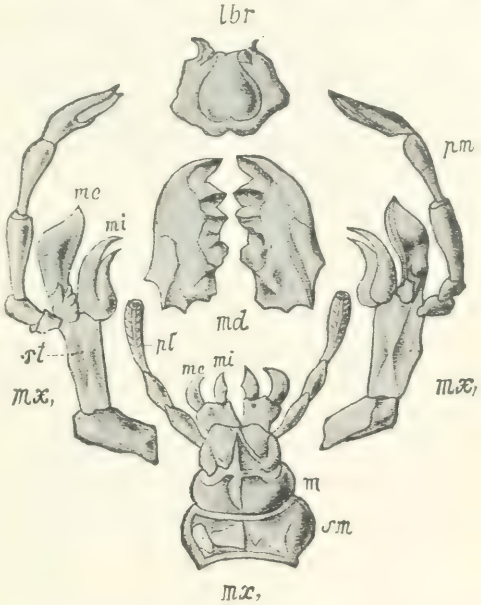



FIG. 190. Mouth parts of the cockroach. *lbr*, labrum; *md*, mandible; *mx*, first or anterior pair of maxillæ; *m*, mentum, formed from the fused second maxillæ; *me* and *mi*, outer and inner divisions of the maxillæ; *pl*, labial palp; *pm*, maxillary palp; *st*, stipes; *sm*, submentum. (From Parker and Haswell's Manual.)

The insects as a group are much more highly differentiated than any animals we have considered up to this point; this is manifest, not only in their structure, but in their modes of life, particularly the care of their young and the living together in colonies with a marked division of labor between different kinds of individuals. They are provided with organs of touch, taste, smell, and hearing, and many have the power of producing sounds; this is effected in different ways in different insects: in some cases it is the rapid movement of the wings as they fly, which produces a humming sound; in some species there are little leaflike structures near the openings of the tracheæ, which by their vibration cause a buzzing as the air is drawn in or forced out; some scrape their legs against their roughened wings; others rub the wings together; and in some the mouth is used to produce sound. Some insects are phosphorescent, emitting a bright light at night; this light is probably due to chemical changes which take place in the fatty substance within the body. As every observer of insects knows, they vary greatly in their food: some derive their nutriment from decaying vegetable or animal matter; some feed upon living plants, others on living animals; and some extract the nectar from flowers, but often give as much as they take by carrying the pollen on their bodies from flower to flower, and thus assist in accomplishing cross fertilization.

FIG. 191. Various forms of insect legs. *a*, *Mantis*, with predatory leg; *b*, [illegible], running leg; *c*, [illegible], springing leg; *d*, *Gryllotalpa*, digging leg; *e*, *Dytiscus*, swimming leg. (From Claus and Sedgwick's Text-book.)

Insects vary greatly in the length of their lives. The sexually

mature life of some is merely a matter of hours, while they have lived for two years or more as larvæ. Queen bees are reported to have attained an age of five years and queen ants of thirteen, but these are of course exceptional. Many insects live only a single season; others hibernate, remaining quiescent during the cold season and becoming active again as warmth returns. Many insect larvæ are aquatic; in such cases, when the larva lies entirely submerged, the tracheæ, if present, are

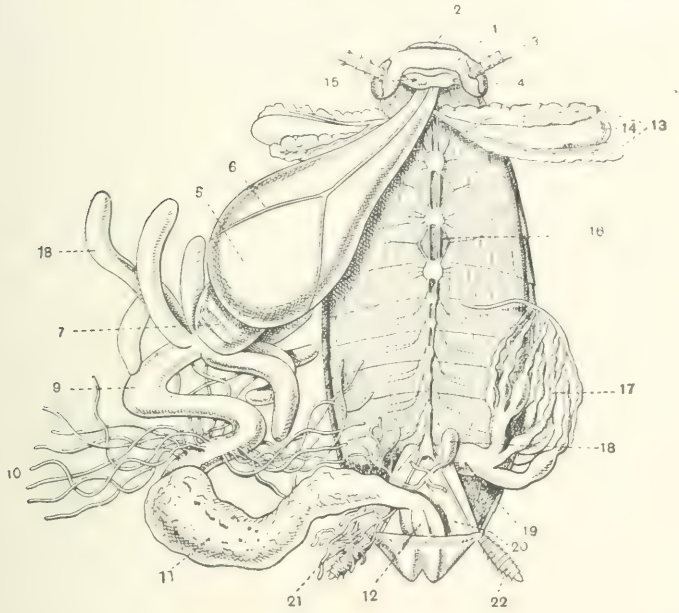



FIG. 192. *Periplaneta.* Female cockroach dissected, from dorsal side; enlarged about two diameters. 1, head; 2, labrum; 3, antenna, cut short; 4, eye; 5, crop; 6, nervous system of crop; 7, gizzard; 8, hepatic cæca; 9, mid-gut or mesenteron; 10, Malpighian tubules; 11, colon; 12, rectum; 13, salivary glands; 14, salivary receptacle; 15, brain; 16, ventral nerve cord with ganglia; 17, ovary; 18, seminal receptacle; 19, oviduct; 20, genital pouch, in which the egg cocoon is formed; 21, colleterial glands; 22, anal cercus. (After Shipley and MacBride.)

non-functional, and there are sometimes little outgrowths from the body wall called tracheal gills or branchiæ, which function as respiratory organs, — these disappear before adult life. There is usually in insects more or less sexual dimorphism: the males as a rule are smaller than the females, more active, and more brilliantly colored. In some cases there are two kinds of

females, — the sexually mature, and others which never attain sexual maturity, such as the workers in a colony of bees.

As we have already noted, the sexes are always separate. Parthenogenesis is not uncommon in several orders, occurring, however, in connection with normal sexual reproduction. Sometimes both males and females are produced in this way, sometimes only males. Temporarily at least some insects may be viviparous. Occasionally, too, we find a condition called pædogenesis, in which ova in female larvæ develop parthenogenetically before the larva has become mature, and produce in this way new larvæ; this may go on for some time, but eventually adult individuals develop.

If insects were to be classified according to the history of development, we should make three groups of them. In the first group belong some of the more primitive insects, in which the young leave the egg in a condition that differs from the adult chiefly in size; such insects are said to develop directly or without a metamorphosis. The second group includes those insects in which a larva is formed, often very different from the adult, without wings or with the most rudimentary wings, and by a series of moults passes more or less gradually into the adult condition; such insects have an incomplete metamorphosis. The third group comprises the remaining insects, in which there is an additional stage. The egg develops into a larva; the larva eventually passes into a quiescent stage, — when it is called the pupa, — during which it takes no food and is gradually transformed into the adult or imago stage. Insects undergoing such changes have a complete metamorphosis. The forms of the larvæ and pupæ are no less varied than the forms of the imagines or adults.

The classification of the insects into orders and suborders has undergone great changes. Certain orders have always been pretty sharply defined, but others have held insects more or less dissimilar, so that their further study has led to a division into more and more groups until we have now about nineteen orders and as many suborders. For our purpose it seems sufficient to divide the class into nine orders, and after taking them up individually, we may briefly note the complete classification as it is more or less generally accepted to-day.

### Order 1. Thysanura

The Thysanura (Gr. *θύσανος*, tassel, and *οὐρά*, tail) are the lowest and simplest of the insects. They are for the most part minute, the largest only about eight millimeters long, the majority much shorter. There are no wings on these insects at any stage in their development; the mouth parts are rudimentary and weak, and the abdomen sometimes bears rudimentary appendages. Further, there is no metamorphosis in their development, but the young animal is like the adult. All the facts point to the low organization of the Thysanura, and they are particularly interesting as affording a sort of connecting link between the more highly developed Hexapoda and the Myriapoda. Some of the commoner representatives of the Thysanura are the bristle tails and fish moths; they have rather long bristles at the posterior end of the abdomen (Fig. 193), and are frequently seen in houses, libraries, and offices. The fish moth is covered with minute, silvery scales like a fish, and feeds upon starch, often injuring starched clothing and the binding of books in this way. The spring tails also belong to this order, so called because of a springlike appendage on the ventral side of the abdomen by means of which they jump about; they are common under stones and wood and sometimes on the surface of quiet water.

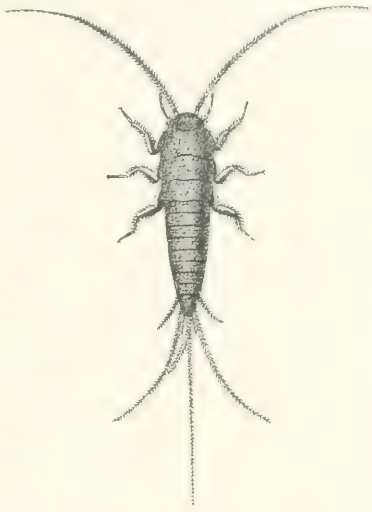


FIG. 193. *Lepisma.* (After Guérin and Percheron, from Parker and Haswell's Textbook.)

### Order 2. Pseudoneuroptera

The Pseudoneuroptera (Gr. *ψευδής*, false, and Neuroptera) formerly constituted a single order with the Neuroptera, and it will be noticed that in the more extended classification they are

divided into seven orders; thus the group as it stands here includes insects which differ considerably in structure, such as the May flies, dragon flies, stone flies, and certain kinds of lice. These animals, with the exception of the wingless lice, have two pairs of thin, membranous wings, usually richly veined. In the May flies, the mouth parts are rudimentary, but in the others they are adapted for biting. A very important characteristic of this order is found in the development, in which there is an incomplete metamorphosis.

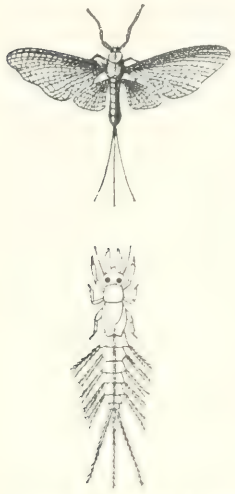


FIG. 194. *Ephemera*, a May fly and larva. (After Guérin and Percheron, from Parker and Haswell's Text-book.)

The May flies (Figs. 194 and 194 bis) are very delicate insects, living near the water and attracted in the evening by bright lights. The wings are thin and transparent, the anterior pair relatively large, the posterior small or absent. To the posterior end of the abdomen two or three long filaments are attached. The adult insect, or imago, generally lives only a few hours, but the aquatic larvæ, or nymphs, may live from one to three years, and are generally provided with tracheal gills.

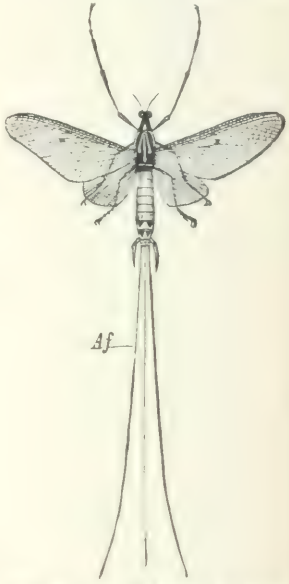



FIG. 194 bis. *Chloroperla grandis*, a May fly. *Af*, anal filaments. (From Claus and Sedgwick's Text-book.)

The dragon flies (Fig. 195), sometimes called darning needles, or mosquito hawks, have the two pairs of wings of nearly equal size. The larvæ are aquatic, and are readily distinguished from other aquatic larvæ by the mouth parts, particularly the second maxillæ fused into a lower lip; this is very large and as it covers the other mouth parts is called the mask; its powerful jaws

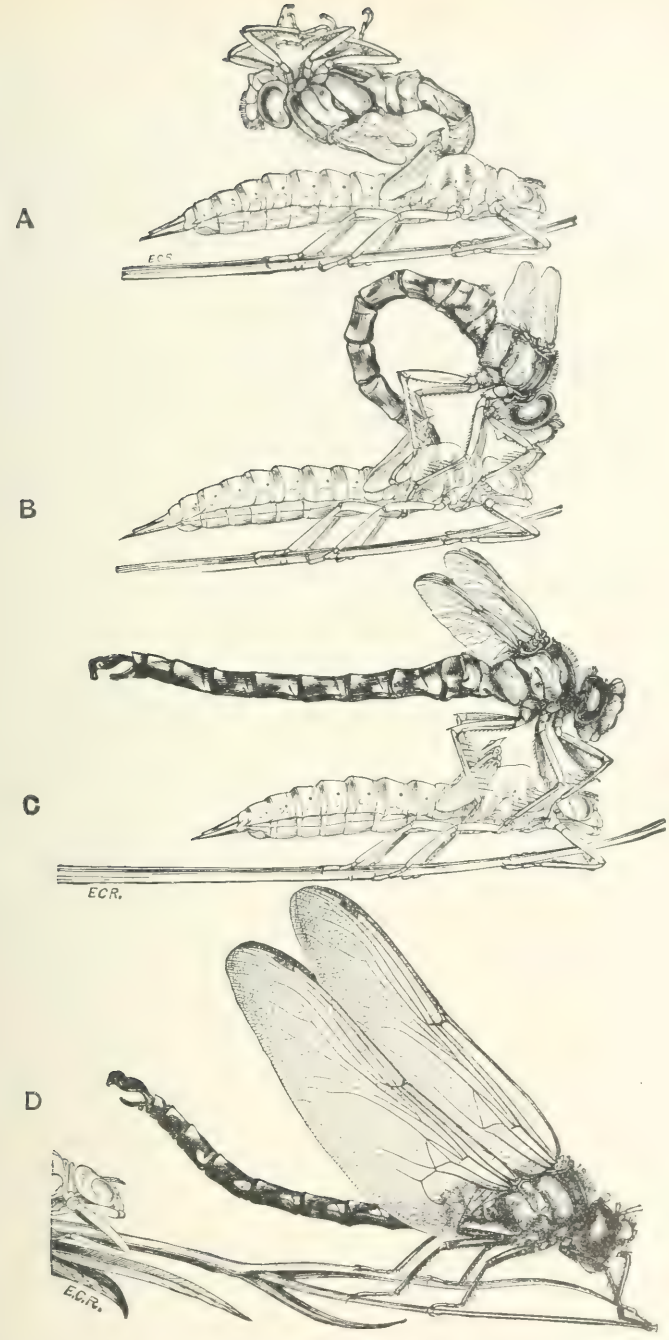



FIG. 195. *Æschna cyanea*, a dragon fly emerging from its pupal skin. A, anterior portion of the body freed; B, withdrawing posterior portion; C, entire body free, wings expanding; D, wings fully expanded, but held vertical until dry. (After Shipley and MacBride.)

serve to catch other aquatic larvæ on which it feeds. The adult dragon fly also is carnivorous and feeds on smaller insects. The stone flies, so called because the larvæ are abundant under stones in brooks, have the posterior pair of wings much larger than the anterior pair, and when at rest they are folded backward over the abdomen. Most species are rather small, but some have wings three centimeters in length.

The termites, or white ants (Fig. 196), are also to be classified here; they may readily be distinguished from the true ants by the light color of most of the individuals and the fact that the abdomen is joined to the thorax by a broad band instead of a narrow stalk. They are essentially tropical insects, though some species are found in the United States. In structure they are among the lowest winged insects, but their habits of life are most interesting. They live in colonies in which four kinds of individuals are represented: the light-colored workers, which are males and females never attaining sexual maturity, and wingless; the soldiers, very similar to the workers, but having enormous heads and jaws; the king and queen, also wingless, but sexually mature and the parents of the colony; and finally there are wingless complemental males and females, which are sexually mature individuals which may serve as substitutes for the true king and queen in founding a colony. All the eggs are laid by the queen, which may increase in size from a centimeter or less to a length of from fifteen to twenty centimeters. The king and queen are kept in a special chamber, and fed by the workers; as the eggs are laid the workers carry them away to other chambers, where they develop and where the larvæ are fed. Eventually many of these larvæ develop into sexually mature winged individuals, black or dark brown in color, which leave the nest, fly for some distance and then alight on the ground, and their wings drop off. Most of them are probably eaten by other animals, but whenever a pair is found by a number of workers a new colony is started. The nests built by the workers are often huge mounds as much as three or four meters high, and are probably formed entirely of undigested particles of wood which the insect has taken into its digestive tract. These termites are great pests in many parts of the tropics, where they eat out the inside of every

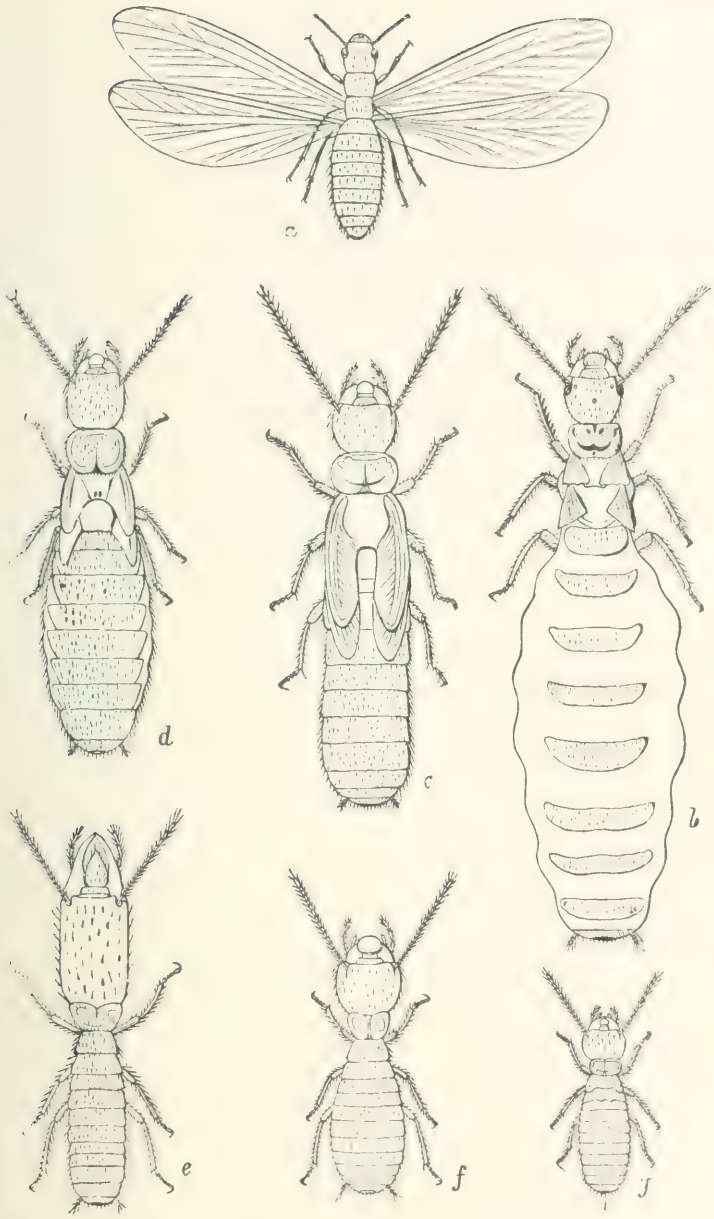



FIG. 196. *Termes lucifugus*, the termite or white ant of Southern Europe; highly magnified. *a*, male; *b*, pregnant female or queen; *c*, pupa; *d*, pupa of the second form; *e*, soldier; *f*, worker; *g*, larva. (From Claus and Sedgwick's Text-book.)

wooden stick or board, leaving only a thin shell on the outside; the legs of tables may be eaten out in this way.

Of the lice belonging to this order, there are the book lice, common in old books and papers, wingless insects with which, however, the little, winged psocids are associated; then there are the bird lice, with biting mouth parts, feeding on feathers, while some closely related genera feed on the hair or wool of many domestic animals. Finally, in this same order must be classified the thrips, unless they are placed in an order by themselves. They are minute insects only two or three millimeters long, and some are common on the daisy and clover blossoms; their two pairs of wings are very narrow and feathery.

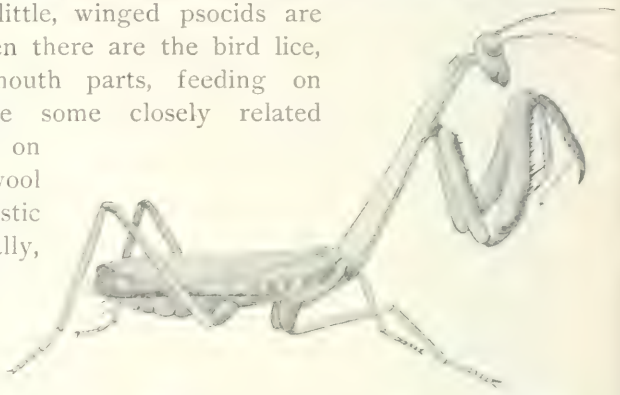


FIG. 197. *Mantis religiosa*, the praying mantis. (Drawn from a preserved specimen.)

## Order 3. Orthoptera

The Orthoptera (Gr. ὀρθός, straight, and πτερόν, wing) include some of our commonest insects, such as the cricket, grasshopper, locust, cockroach, katydid, and earwig. They have two pairs of wings, the anterior pair thickened and straight, the posterior pair thin, larger, and folded lengthwise like a fan when at rest. But many genera are wingless, and some have the anterior pair only. The mouth parts are well developed, and all the Orthoptera, with the exception of the praying mantis (Fig. 197), are more or less injurious to vegetation. Many females have a special appendage at the posterior end of the

FIG. 198. *Labidura riparia*, ♂, enlarged; an earwig. (From Ludwig-Leunis' Synopsis der Thierkunde.)

abdomen which assists in placing the eggs in position as they are laid; this is called the ovipositor and differs in form in the different groups.

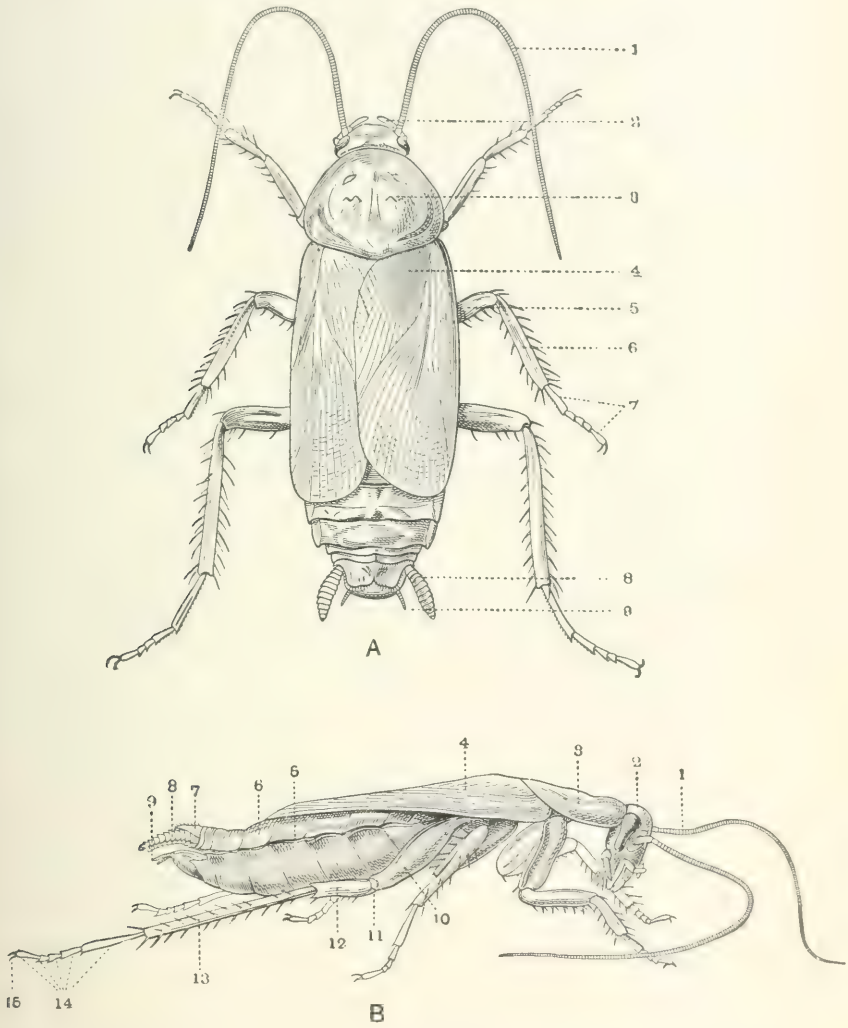



FIG. 199. *Periplaneta orientalis*, male cockroach; enlarged two diameters. A. 1, antenna; 2, palp of first maxilla; 3, prothorax; 4, anterior wings; 5, femur of second leg; 6, tibia; 7, tarsus; 8, anal cerci; 9, styles. B. 1, antenna; 2, head; 3, prothorax; 4, anterior wing; 5, soft skin between terga and sterna; 6, sixth abdominal tergum; 7, split portion of tenth abdominal tergum; 8, anal cerci; 9, styles; 10, coxa of third leg; 11, trochanter; 12, femur; 13, tibia; 14, tarsus; 15, claws. (From Shipley and MacBride's Zoölogy.)

The earwigs (Fig. 198) feed on fruit and flowers; they are rare in the United States; our common species is less than half a centimeter long. They are nocturnal in habit, and the same is true of the cockroaches (Fig. 199), which have a wider distribution, and are common both in and out of doors. Many are wingless, and some attain a considerable size. The curious walking stick (Fig. 200) is a member of this order, and also the leaf insect (Fig. 201), which so closely resembles a green leaf. The crickets (Fig. 202), locusts (Fig. 203), and katydids are all jumping Orthoptera. The true locusts have short antennæ, the true grasshoppers have long antennæ, and in both the female usually has a prominent ovipositor. The crickets have long antennæ, and a long, slender ovipositor.

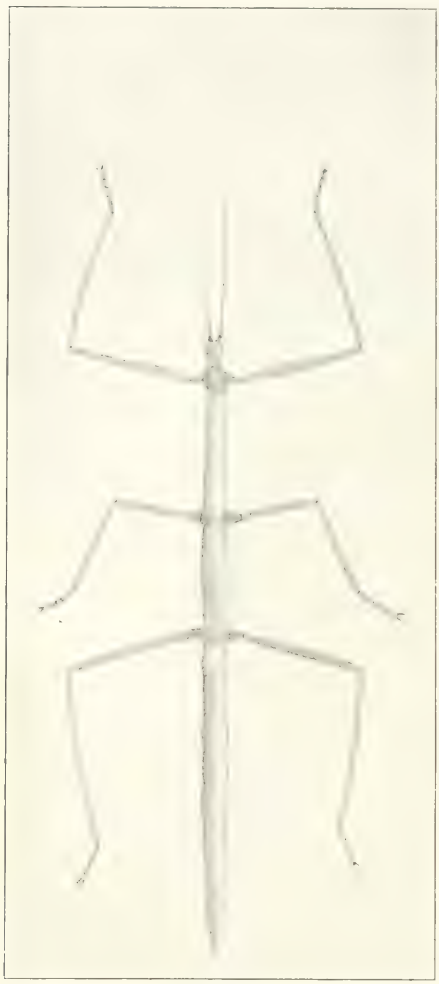


FIG. 200. *Diapheromera femorata*, ♀, the common walking stick of the United States; natural size. (Drawn from specimen.)

### Order 4. Hemiptera

The Hemiptera (Gr. *ἡμί*, half, and *πτερόν*, wing), sometimes called the Rhynchota (Gr. *ῥύγχος*, beak), constitute a large order of insects, presenting a great diversity of form and habit of life. Many are of considerable economic importance because of the injury they do to vegetation. In general they have two pairs

of more or less membranous wings, with mouth parts adapted to sucking, and pass through an incomplete metamorphosis in

FIG. 201. *Phyllium siccifolium*, the leaf insect. (From Brehm's Thierleben.)

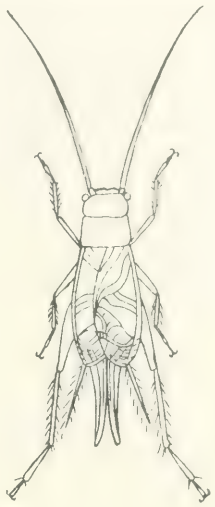


FIG. 202. *Gryllus domesticus*, ♂, the common dark brown cricket. (From Ludwig-Leunis' Synopsis der Thierkunde.)

the course of their development. They include various kinds of bugs and lice. These insects may be considered best under three groups: the first comprises those wingless parasites on man and other mammals, commonly called lice; the second has the anterior pair of wings of uniform thickness throughout; the third has the anterior pair of wings thickened at the base and thin at the tip; these three groups are recognized as suborders in the system of classification.

The first includes three species of lice found on the human body; they pierce the skin and suck the blood; one infests the hair of the

FIG. 203. *Locusta*. (From Cuvier's Animal Kingdom.)

head, another the other hairy portions of the body, and the third the skin, particularly of the chest and back. This last is interesting because of the variation in color which it exhibits according to the color of the skin of its host; thus on the European it is whitish, on the Chinaman yellowish, on the African black, and so on. Lice very similar to these, but placed in another genus, may infest all the domestic animals.

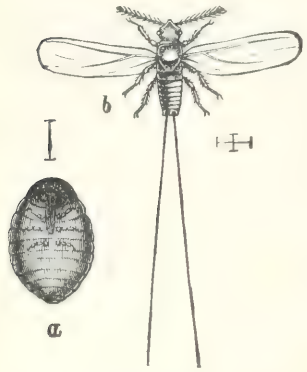



FIG. 204. *Coccus cacti*, the cochineal insect of Mexico. *a*, female; *b*, male. (After Burmeister, from Claus and Sedgwick's Text-book.)

The second group, having the wings of uniform thickness, is further distinguished by the absence of a neck, the thorax and head being closely approximated. To this group belong the scale insects and mealy bugs, which are such a pest in greenhouses, and in warm regions to out-of-door vegetation as well (Fig. 204). These are small insects; the male is usually provided with a single pair of thin, membranous wings, the female is wingless and the body scalelike or gall-like. Some of these insects, however, are of considerable

FIG. 205. *Aphis* [illegible] and larva. (From Cuvier's Animal Kingdom.)

commercial importance, such as the cochineal insect, *Coccus cacti* (Fig. 204); this is a native of Mexico, but is now cultivated in many other countries, and from the dried adult females cochineal is obtained. Shellac and China wax are also prepared from substances formed by similar insects. The plant lice or

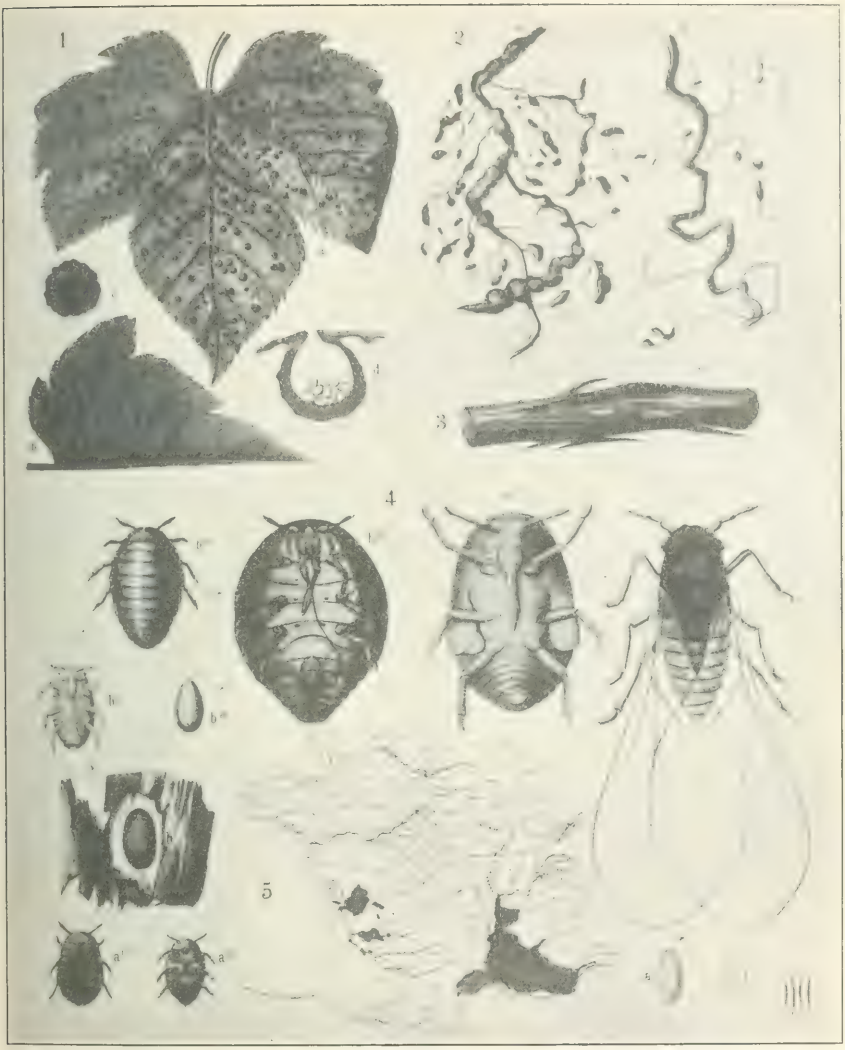


FIG. 206. *Phylloxera vastatrix.* 1. *a*, under surface of a leaf of an American grape vine, showing galls of Phylloxera; *b*, upper surface of leaf showing entrances of galls; *c*, exterior of gall enlarged; *d*, gall in section with eggs; 2. *a* and *b*, rootlets of grape vines with swellings caused by the punctures of the Phylloxera; 3, root of a diseased vine with hibernating colonies of apterous females under the bark; 4, development of Phylloxera; *a*, egg laid by a winged female ($c^{II}$) on the wood of the vine above ground, which develops into the apterous female, $a^{II}$, containing a single egg; $a^{I}$, egg laid by $c^{II}$, which develops into apterous male, $a^{III}$; *b*, fertilized egg laid by $a^{II}$ under the bark above ground; from eggs of this sort only subterranean, apterous females develop, seen in $b^{I}$, $b^{II}$, $b^{III}$, in successive stages of development; $b^{IV}$, egg laid by $b^{III}$ on the roots of the vine; it develops parthenogenetically and a long series of parthenogenetic generations follows, but in the autumn these eggs develop into pupæ, $c^{I}$, from which soon the winged females, $c^{II}$, emerge and lay their eggs, *a* and $a^{I}$, above ground; 5, map of France showing by the dark spots the distribution of Phylloxera in 1877. (Photographed from a Leuckart-Nitsche wall chart, by the author; permission of Dr. C. Chun.)

Aphids (Fig. 205) belong here; they are for the most part not more than six or seven millimeters long, some with two pairs of wings, some without any, and many secrete a sweet, sticky substance from the abdomen, called honeydew, upon which other insects, such as bees, wasps, and ants, feed.

There are many kinds of aphids: the woolly aphids, which cause the alder blight, the beech tree blight, the woolly louse of the apple tree, the cherry tree aphis, the hop aphis, the peach tree aphis, which causes the leaves to curl up, though this is often due to other causes as well, the elm gall and the poplar leaf gall, and one of the most important, Phylloxera, which has done so much injury to the grape vines of Southern France. The grape Phylloxera (Fig. 206) attacks only certain species of grapes. The larva hibernates in the ground, and in the spring develops into a wingless female, which deposits her eggs on the young roots of vines; the roots then appear swollen and knotty, and eventually die. From these eggs young are produced parthenogenetically, mostly wingless like the parent; but eventually winged forms are developed, which make their way above ground and spread to neighboring vines. These deposit eggs, some small, some large,

FIG. 207. *Enchenopa*, a tree hopper common on locust trees. Lateral aspect and anterior view; natural size, about thirteen millimeters long. (Drawn from specimen by the author.)

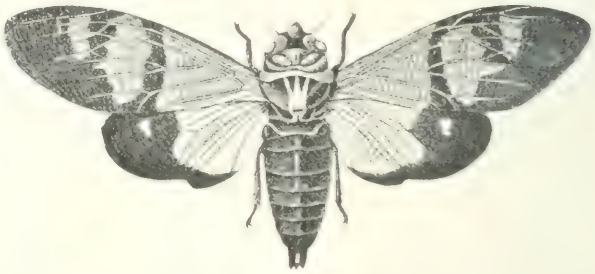


FIG. 208. *Cicada*. (After Guérin and Percheron, from Parker and Haswell's Text-book.)

which develop parthenogenetically into males and females respectively. Each pair of these sexual individuals gives rise to a single egg, which develops into a wingless form like the original hibernating insect. This last-formed female may go

below ground, or may remain on the leaves of the vine, forming galls and laying eggs which develop parthenogenetically. Many acres of vineyard have been devastated by this insect.

In this same suborder are many curious insects, such as the tree hoppers (Fig. 207), little animals shaped like a beechnut, doing no particular harm; the leaf hoppers, found on grain, grapevines, and roses; the spittle insect, whose larvæ produce the so-called "frog spittle" seen on grass stems during the summer; and the cicadas (Fig. 208), whose music is familiar in country places. The sound is produced by the males, which have two large, parchment-like sacs at the base of the abdomen, provided with strong muscles, which cause them to vibrate. Our commonest cicada is about five centimeters in length, when the wings are closed, black and green in color, and requires about two years for its complete metamorphosis. The periodical cicada, or seventeen-year cicada, incorrectly called locust, lives only a few weeks as an adult; it deposits its eggs on trees, and the larvæ pass to the ground, where they remain for another seventeen years; at the end of that time they emerge and become mature. Another species lives only thirteen years underground.

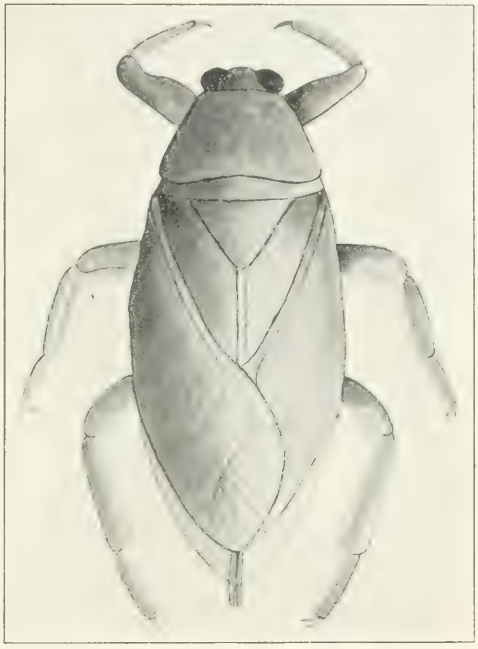


FIG. 209. *Belostoma*, the giant water bug, natural size. (Drawn from a preserved specimen.)

The third group of Hemiptera has the wings thickened at the base and thin at the tip, and further is provided with a more or less distinct neck. According to their habits they might be classified as aquatic, semiaquatic, and terrestrial. The

aquatic genera live under fresh water, coming occasionally to the surface for air, and include the curiously shaped water boatmen and the giant water bugs, represented by Belostoma (Fig. 209), which in the United States attains a length of from four and a half to six centimeters, and in Brazil may be as much as ten centimeters in length. The semiaquatic are represented by the long-legged water striders, which run about on the surface of the water. The terrestrial include such insects as the squash bug, particularly injurious to young plants in the kitchen garden; the chinch bug, a great grain destroyer; the red bug or cotton stainer, particularly harmful in Florida and the West Indies to the cotton plant; and the common bedbug (Fig. 210), a household pest, reddish brown and wingless, which may attain a length of half a centimeter. Belonging to this same suborder, but in a different family, is the big bedbug found in beds in some parts of this country; it attains a length of two and a half centimeters, is black in color with red markings, and produces a very painful wound. Here, too, belongs the masked bedbug hunter, living in houses, and attaining a length of from one and a half to two centimeters; it preys upon bedbugs, but its bite is said to be almost as painful as that of a snake.

FIG. 210. *Acanthia lectularius*, a bedbug, enlarged. (From Lampert's "Insekten der Tierkunde.")

## Order 5. Neuroptera

The Neuroptera (Gr. *νεῦρον*, nerve, and *πτερόν*, wing) bear a close resemblance to the Pseudoneuroptera in the adult stage. There are two pairs of membranous wings, usually richly veined, and the mouth parts are adapted for biting except in one group, the caddice flies, in which they are rudimentary. But the development is attended by a complete metamorphosis, whereas in the Pseudoneuroptera it is incomplete. The order is not homogeneous, and in the more extended classification is divided into three orders. The group includes insects known commonly as the hellgramite fly, the ant-lions, the scorpion flies, the caddice flies, and the lace-winged flies.

The hellgramite fly is a large insect with long antennæ, and in the male with very long mandibles, while the wings, when

spread, measure from ten to thirteen and a half centimeters from tip to tip. The larva is better known perhaps than the adult fly; it is much used by anglers for bait under the name of

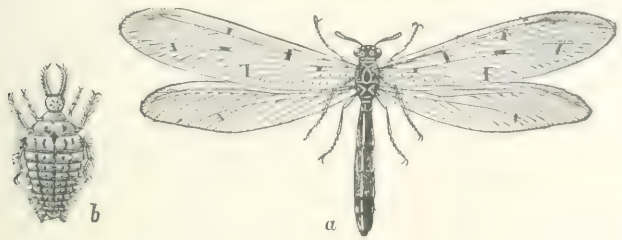



FIG. 211. *a*, *Myrmeleon formicarius*, an adult ant-lion; *b*, the larva. (From Claus and Sedgwick's Text-book.)

"dobson." The larvæ are aquatic and abundant under stones in swiftly flowing brooks; they attain a length of seven and a half centimeters, are carnivorous in habit, feeding on the larvæ of other insects, and they lead this aquatic life for about three years. Then they come out of the water, pass into the pupal stage, and in the course of a few weeks become adult insects.

FIG. 212. *Panorpa communis*, ♂, a scorpion fly. (From Ludwig-Leunis' Synopsis der Thierkunde.)

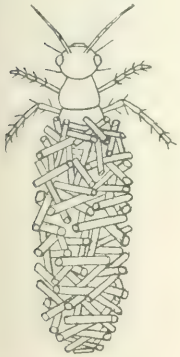


FIG. 213. A caddice-fly larva, partly protruding from its case. (From Ludwig-Leunis' Synopsis der Thierkunde.)

The adult ant-lions (Fig. 211) are graceful insects, somewhat resembling the dragon flies; their larvæ, to which the popular name is particularly applied, are conspicuous because of the little pitfalls they dig in the sand for catching their prey. The larva lies buried at the bottom of this pit with its jaws projecting, and when an ant or similar animal steps on the edge of the hole, the sand giving way it falls into the jaws of the ant-lion. The scorpion flies (Fig. 212) are so called because of the peculiar shape of the posterior part of the abdomen in the male; this is not unlike the corresponding region in a scorpion, but is not provided with a sting.

The caddice flies are better known to the ordinary observer in their larval condition, when they are called caddice worms (Fig. 213). The adult is a mothlike insect, with wings and body thickly covered with hairs, and often with very long antennæ. The larvæ are wormlike animals living in the water in streams or ponds, and conspicuous because of the great variety of tube-shaped houses that they build for themselves out of small stones or sticks or leaves. The parts are held together by delicate threads of silk which the larvæ spin from their mouths; the tubes are also lined with silk, and in some cases the tube is formed entirely of this material.

### Order 6. Lepidoptera

The Lepidoptera (Gr. λεπίς, scale, and πτερόν, wing), or scaly winged insects, constitute the most sharply defined order of Hexapoda. They have two pairs of membranous wings, which

Fig. 214. [illegible]; butterfly or imago.
(After Riley, from Parker and Haswell's Manual.)

are covered with overlapping scales arranged in more or less regular rows. The body of the insect is covered with very fine hairs, in some species relatively long, and these occur at times on portions of the wings; the scales are to be regarded as short, flattened hairs. The mouth parts are adapted for sucking; the mandibles are rudimentary, and the maxillæ usually form a proboscis, sometimes very long and spirally coiled when not in use. In this order the metamorphosis is complete. Its members are called moths, skippers, and butterflies. The legs are of use chiefly for supporting the body while at rest, and in many

butterflies the first pair is very rudimentary so that only two pairs are well developed. The adults generally take little food, and the nectar of flowers is their chief food supply; as a rule they live but a short time, although some hibernate and thus live from one season to another. The colors are often very brilliant, and there is frequently considerable sexual dimorphism, the males and females differing from one another in color, size, and shape of wings, and form of antennæ. In some butterflies there is a seasonal dimorphism, the imagines or adults which appear in the early summer differing from those which appear in the autumn.

The butterflies and moths may be distinguished from one another by the structure of the antennæ: in the butterflies (Fig. 214) they are always knobbed or enlarged at the free extremity; this is never the case with the moths, whose antennæ are very variously shaped, sometimes feathery (Fig. 216), sometimes greatly attenuated; in the skippers there is a thickening near the extremity of the antennæ, but they always terminate in a sharp point. The method of folding the wings when at rest is also different. In butterflies the wings are brought together vertically over the dorsal side of the body; in moths they may remain extended horizontally, or may be folded flatwise over the abdomen, or be wrapped around the body.

FIG. 215. Cocoon of the silkworm moth, *Bombyx mori*, about natural size. (After Shipley and MacBride.)

The larval stage of the Lepidoptera is the caterpillar (Fig. 214); it has three pairs of thoracic legs, and either two pairs or five pairs on the abdomen; the pupa is frequently called a chrysalis (Fig. 214), and is often inclosed in a cocoon (Fig. 215), which the caterpillar forms from the secretion of the two silk glands which open by a common aperture at the mouth. The order is of much economic interest because of the larvæ, many of which are most serious pests, not only to the farmer, but to whole communities. Every one is familiar with the clothes moth, whose caterpillar eats woolen garments and furs; the little moths or millers, as they are often popularly called, are frequently seen flying about rooms in the evening. The larva of a similar moth attacks

carpets. The injury which larvæ do to vegetation varies with the feeding habits; thus we have the group of cutworms, larvæ of moths, which cut off young garden plants near the root, while some ascend dwarf fruit trees and bite off the fruit buds. The larvæ of other moths form the group of borers, which bore into the roots of plants or from the roots into the stalk; some of the more common are the peach tree, grape root, currant, squash vine, and dahlia borers. Some caterpillars roll up the leaves of plants, fastening them together with silk when they build their cocoons; some of the more common of these are the cotton leaf, peach leaf, grape leaf, and strawberry leaf rollers. Some of the greatest pests are the caterpillars which feed on the leaves of plants and bushes; the cankerworm is a well-known example; it attacks the fruit trees, apple, cherry, plum, as well as the elm and others. The currant and gooseberry worms are caterpillars of moths, and the same is true of the cranberry vine worms, which have caused an enormous loss in the cranberry bogs; they are sometimes called fireworms, because the plants look as though a fire had passed over them when the larvæ have completed their work.

One of the most destructive Lepidoptera has been the gypsy moth (Fig. 216), which feeds on the leaves of fruit and forest trees. Until a few years ago it was unknown in America, but

Fig. 216. [illegible] the gypsy moth. 1, male; 2, female; natural size. [Insect from specimen.]

had for at least a century and a half been a pest in most of the countries of Europe. It was accidentally introduced into the town of Medford, near Boston, Massachusetts, about 1869, by a French naturalist, and has since spread over such large areas that the state has been compelled to undertake the work of checking its advance.

There is one group of moths, however, which are very valuable, — the silkworm moths; of these there are about a dozen species. The largest and strongest of the domesticated species is the Chinese silkworm, *Bombyx mori* (Fig. 217), which feeds on the mulberry and produces a very fine thread. It is extensively cultivated in Asia and Europe. The cocoon is white or yellowish white, and about three centimeters long by nearly half

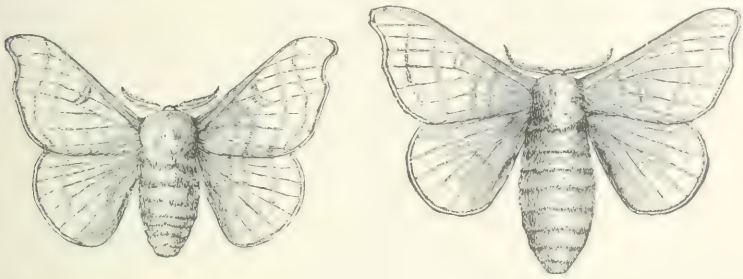


FIG. 217. *Bombyx mori*, the silkworm moth, male and female. (After Shipley and MacBride.)

as broad. The most hardy silkworm in the United States is *Telea polyphemus*, which feeds on the oak. The silk is coarser than that of the Chinese worm, but has a rich gloss, and is readily unwound from the cocoon.

### Order 7. Diptera

The Diptera (Gr. δίς, two, and πτερόν, wing) include all the flies, properly so called, such as the common house fly, the horse-fly, the long-legged crane fly, the mosquito, and many others. They have only a single pair of wings, which are thin, transparent and membranous, and attached to the mesothorax; the posterior wings are represented by knobbed, threadlike processes, borne on the metathorax, and called the halters. The mouth parts are adapted to piercing and sucking, and the metamorphosis is complete. This order has a wider geographical distribution than any other group of insects. A few flies are parasitic in the adult state, such as the sheep tick, the horse louse, and others which live on bats and some birds. The larvæ are entirely without feet and develop in various places; some feed on animals, some are known as maggots and suck up fluids or semi-

fluid substances. Thus we find larvæ developing in caterpillars, in mammals either on the skin, or under the skin producing ulcers, in the nasal chamber, or even in the stomach. Others grow in cherries and other fruits; some occur in stagnant water, in sewers, in decaying animal or vegetable matter, in the earth; and the gall flies deposit their eggs on plants, which develop galls about them. The larvæ of the Hessian fly, *Cecidomyia destructor* (Fig. 218), is very destructive to crops in the United States, as it sucks the juices from the growing stalks of grain. The botflies of the horse and the ox have very hairy bodies, so that they look not unlike some of the bees.

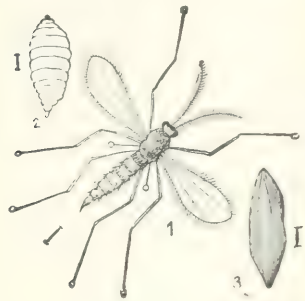



FIG. 218. *Cecidomyia destructor*, the Hessian fly. 1, adult insect; 2, larva; 3, pupa; all enlarged. (After Shipley and MacBride.)

In the common horsefly it is only the female that bites, the male being without any organs for piercing. The same is true of the mosquitoes, whose wingless larvæ (Fig. 219) can be seen in great numbers in a body of standing water in the summer time; here the females become a veritable pest in many countries and also very dangerous when we remember that one genus, Anopheles (Fig. 220), is the agent in transmitting the malarial parasite to man, and that infection with the parasitic roundworm, Filaria, is acquired in the same way; it seems, too, to be pretty well established that yellow fever is likewise transmitted by a mosquito of the genus Culex, or Stegomyia, as it has more recently been called. In this same order we may

FIG. 219. *Culex*. The adult male mosquito and the larva. (After Guérin and Percheron, from Parker and Haswell's Manual.)

place the fleas (Fig. 221), although in the more extended classification they occupy an order by themselves. They are wingless,

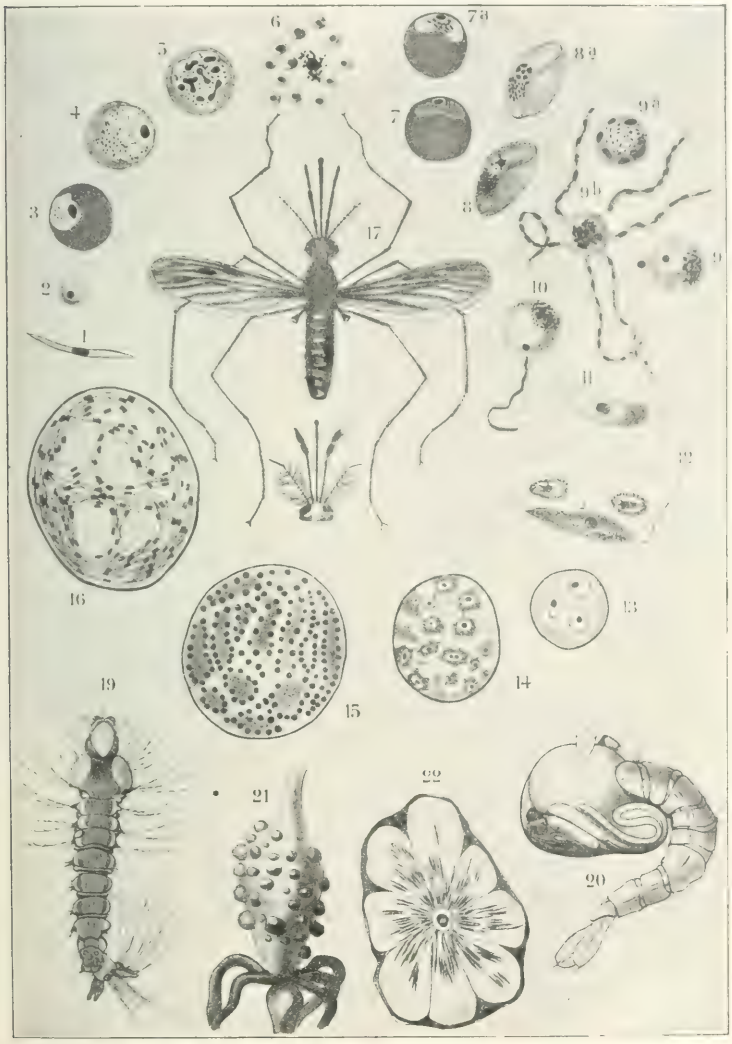



FIG. 220. *Plasmodium*, the malaria parasite, 1–16, and *Anopheles claviger*, the mosquito, 17–22. For 1–16 see Fig. 16, page 36. 17, adult female malarial mosquito; head of male below; 19, larva; 20, pupa; 21, stomach of mosquito showing tumors produced by the developing oöcysts of the parasite; 22, cross section of salivary gland of mosquito, showing in its cells sporozoites which have wandered in from the tumors of 21, and are now ready to pass into the blood with the bite of the mosquito. (After Leuckart-Chun's wall chart, from Sedgwick's Sanitary Science.)

with the body compressed laterally, and live for the most part as external parasites on the skin of mammals. The larvæ in their form and habits of life resemble the larvæ of some Diptera.

FIG. 221. *a*, *Ixodes ricinus* ♀; *A*, antenna; *Mt*, mouth-parts; *b*, *Ixodes ricinus*, larva. Highly magnified. (From Claus and Sedgwick's Text-book.)

## Order 8. Coleoptera

The Coleoptera (Gr. κολεός, sheath, and πτερόν, wing) are commonly called beetles and include a very large number of species. They are readily distinguished from other insects by the thickened anterior wings (Fig. 222), which are called the elytra and form covers for the delicate, membranous posterior wings, which are folded beneath them; in a few cases the posterior are wanting. The mouth parts in this order are adapted to biting, and the development is attended by a complete metamorphosis. The prothorax is often relatively larger than in many insects, and is sharply marked off from the mesothorax, so that, seen from the dorsal side, the body appears to consist of head, prothorax, and elytra, which in most beetles completely cover the abdomen. The antennæ vary greatly both in length and shape. The legs are for locomotion and differ according to the habits of the species.

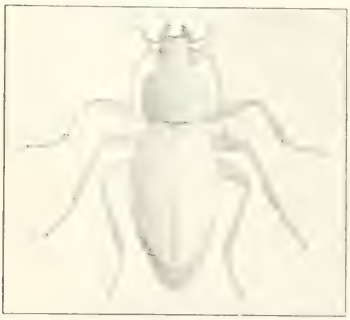


FIG. 222. *Calosoma*, a ground beetle with green-gold wings. (Drawn from specimen.)

Generally there is more or less sexual dimorphism; the males and females differ in the form and size of the antennæ and also in the general size, form, and color of the body. The male is provided with a large, horny penis. The larvæ are more or less grublike, with or without legs, and usually have mouth parts which are formed for biting or gnawing. Many larvæ live several years before passing into pupæ. The adult beetles vary from minute species only one or two millimeters in length to the huge stag beetles of the tropics, measuring fifteen centimeters. Many beetles are very beautiful, being a brilliant metallic green or red in color; the goldsmith beetle is a bright yellow above and green below. Some South American beetles owe their color to minute scales, as in the diamond beetle, whose black elytra are covered with minute pits, and these are lined with very small scales of a predominant green color, but refracting the light so as to give various brilliant prismatic effects; this beetle is about three centimeters in length.

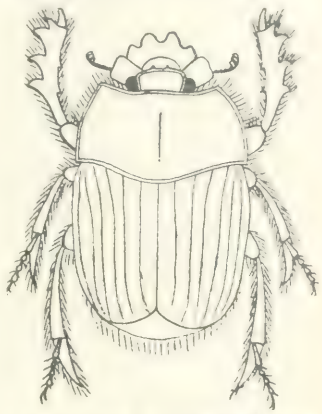


FIG. 223. *Ateuchus* (Scarabæus) *sacer*, the sacred scarab beetle. (From Ludwig-Leunis' Synopsis der Thierkunde.)

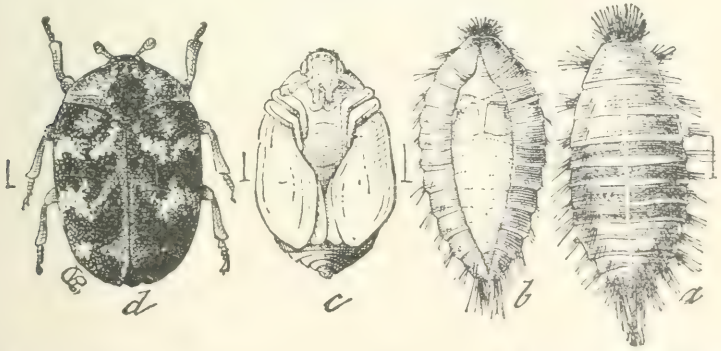


FIG. 224. *Anthrenus scrophulariæ*, the carpet beetle. *a*, pupa; *b*, larva; *c*, pupa; *d*, imago. (After Riley, from Parker and Haswell's Manual.)

While the majority of the beetles are distinctly terrestrial insects, some live in the water and breathe there by means of a

film of air which adheres to the minute hairs on the ventral surface of the body; they come to the surface from time to time to renew this air. The brilliant green Spanish flies belong to the beetles; also the little ladybirds, or ladybugs, of which there are over a thousand species, the weevils or boring beetles, and the glow-worms or fire flies. Here, too, are the scarabs, dull black beetles, sometimes from two and a half to three centimeters long, of which the sacred Egyptian scarab, *Scarabæus sacer* (Fig. 223), is familiar from Egyptian carvings.

The buffalo bug or carpet beetle, *Anthrenus scrophulariæ* (Fig. 224), is a very troublesome beetle apparently imported to the United States from Europe; it is only about three millimeters long, and feeds out of doors on the pollen of flowers, indoors on carpets and all kinds of woolen goods as well as on furs and similar objects; the larva, which is covered with long brown hairs, is, as usual with insects, more destructive than the adult. The adult buffalo bug is black marked with white and brick-red spots, and has the elytra covered with minute scales.

Many of the weevils are destructive to various plants, trees, and fruits; such are the potato-stalk weevil, the white-pine weevil, the pea weevil, and the plum weevil, which stings the plum and deposits an egg within the fruit; the cherry, peach, and quince are attacked in a similar way. Many larvæ are very destructive borers in wood, particularly the larvæ of the long-horned beetles, which have very long antennæ; these larvæ sometimes live for two or three years before passing into the pupal stage; when about to do so they often make a sort of cocoon for themselves out of fine chips of wood, which they fasten together.

Some beetles feed on the leaves of plants or on the petals of flowers. The rose bug or rose chafer is a familiar example. One of the most troublesome in this country has been the Colorado or potato beetle, *Doryphora decemlineata* (Fig. 225). Both the adult beetle and the larva feed on the potato leaves. The bright yellow eggs are deposited in groups on the under surface of the potato leaves; the larvæ grow rapidly and then descend into the ground, where they pass into the pupal stage, and shortly after emerge as fully developed beetles within a month after the time of hatching from the egg. Some beetle

FIG. 225. *Doryphora decemlineata*, the Colorado or potato beetle. 1, portion of a potato plant: *a*, eggs, *b*, larvæ, and *c*, beetle; 2, full-grown larva; 3 and 4, pupæ; 5, adult beetle; 6, antenna; 7, mandible, *a*, from above, *b*, from below; 8 *a*, first maxillæ; 8 *b*, second maxillæ; 9 *a*, entire leg; 9 *b*, tarsus from above. (Photographed from a Leuckart-Nitsche wall chart by the author; permission of Dr. C. Chun.)

larvæ feed on the roots of plants and have a very hard outer skin, so that they have received the popular name of wireworms.

## Order 9. Hymenoptera

The Hymenoptera (Gr. *ὑμήν*, membrane, and *πτερόν*, wing) are represented by such insects as the ants, bees, and wasps

They have two pairs of transparent, membranous wings, not richly veined, and the posterior pair smaller than the anterior. These two pairs of wings are attached together during flight, by little hooks on their adjacent edges. The mouth parts are adapted to biting and sucking. Generally the first or the first two segments of the abdomen are very narrow, forming a stalk connecting the thorax with the remainder of the abdomen. There is a complete metamorphosis. The male possesses a large, protrusible penis, and in the female the abdomen is provided with an ovipositor or with a sting.

The larvæ of most of the Hymenoptera are grublike, without any appendages, but in many of the wasps they closely resemble caterpillars and feed upon leaves; they have three pairs of thoracic legs and from six to eight pairs of abdominal legs; thus they are readily distinguished from the true caterpillars, which never have over five pairs of appendages on the abdomen. The gall wasps (Fig. 226) deposit their eggs on the leaves of various plants or trees; when the female places the egg, she pierces the leaf and there results a very rapid growth of the plant tissue about the developing larva, thus forming a gall; in some cases, however, it appears that it is not the sting of the parent, but the action of the young larvæ themselves, that leads to gall formation. The galls of some oaks contain a considerable amount of tannic acid and so have a certain industrial value.

Very interesting Hymenoptera are the ichneumon flies, which constitute a very large group. The female deposits her eggs almost exclusively within or upon the bodies of other insects, usually upon the larvæ. The ichneumon larvæ then feed upon the larval host, and finally spin cocoons for themselves within or upon them. It is not uncommon to find caterpillars completely covered with the minute cocoöns of these insects; in this way the ichneumon flies are of considerable advantage in destroying these pests.

The ants possess a relatively high degree of psychical development. They live in communities with a marked division of labor; the sexually functional males and females are typical winged Hymenoptera, but the majority of the members of a colony are wingless, and are nonfunctional females, which are the workers (Fig. 227). They are sometimes divided into two

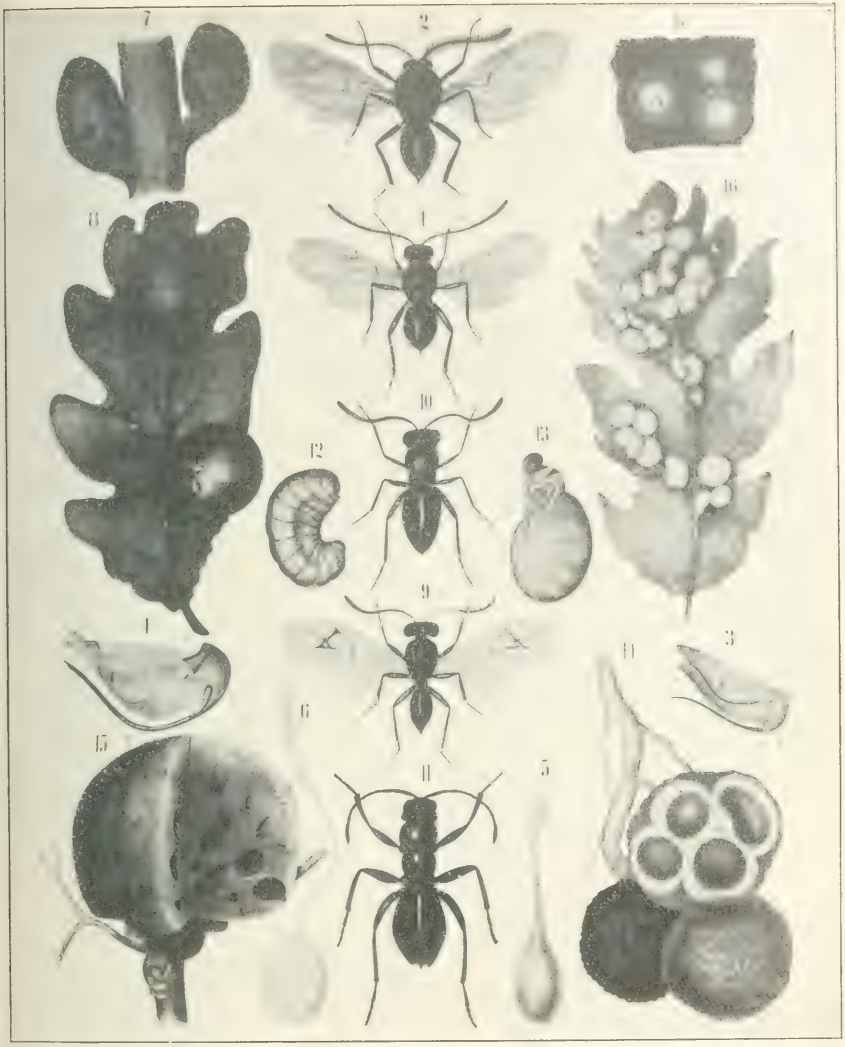


FIG. 226. Various gall wasps and galls of the oak. 1, *Spathegaster taschenbergi*, male, natural size, two and a half millimeters, the sexual, summer generation. 2, *Dryophanta scutellaris*, natural size, four millimeters, the asexual, winter generation of 1, appearing in the spring; 3, ovipositor of female of 1; 4, ovipositor of female of 2; 5, egg of 1; 6, egg of 2; 7, galls produced by 2, natural size, two to three millimeters; 8, galls produced by 1, natural size, up to two centimeters. 9, *Teras terminalis*, male, natural size, three millimeters long, the sexual, summer generation; 10, wingless female of 9; natural size, three and a half millimeters long. 11, *Biorhiza aptera*, wingless, asexual, winter generation; 12, larva of 11, seven millimeters long; 13, pupa of 11, four to six millimeters long; 14, galls of 11 on the roots of the oak, one cut to show larval chambers, natural size, ten to twenty millimeters; 15, gall of 10 on leaf buds of oak, cut to show larval chambers, natural size, up to four centimeters. 16, *Trigonaspis crustalis*, galls of sexual, summer generation on under surface of oak leaf. 17, *Biorhiza renum*, winter generation of 16, galls on the bark of the oak. (Photographed from a Leuckart-Nitsche wall chart by the author; permission of Dr. C. Chun.)

groups, the true workers and the soldiers, and, like the mature females, they possess a poison gland from which they eject formic acid into the wounds which they inflict. Their nests consist of chambers and passages, which they construct in decayed wood or in the earth or in mounds, often of considerable size, which they built. Many ants make definite roads and even construct tunnels below the surface of the ground, often leading from a favorite food supply to their nests. Ants are very fond of the honeydew secreted by the aphids or plant lice, and even keep these insects in their nests as a permanent source of supply. Ants have very highly developed the power of recognizing as

FIG. 227. *Formica rufa*, the wood ant. 1, female; 2, male; 3, worker. (After Shipley and M... Bat...)

friends the members of their own colony, wherever they may meet them, and an ant from any other colony is at once recognized as an enemy and treated as such.

The solitary digging wasps deposit their eggs in holes, which they make in the sand or in earth, or in wood, and with the eggs they place a sufficient quantity of food to supply the growing larva. This food consists of other insects or spiders, which the wasp paralyzes by stinging them, often in the large ganglion in the thorax, so that the animal is not killed, but is powerless to move and remains fresh until eaten by the larva. The nests of the social wasps (Fig. 228) are very familiar objects; they are made of bits of gnawed wood formed into a pulp like paper, and may consist merely of a mass of hexagonal cells or chambers in which the eggs are deposited and the larvæ develop. Often, however, these cells are inclosed in a chamber made by successive layers of paper formed about them, with one large opening, and these chambers often contain several layers of hexagonal cells; these cells are generally used for several generations of larvæ. As a rule it is only the females that survive the winter, hibernating under stones or logs.

The bees (Fig. 229) represent the highest type of development of the Hymenoptera and possibly of the entire Insecta as well. They have the body and posterior pair of legs densely hairy, and these serve to carry the pollen on which the larvæ are fed in part. Some bees are solitary, building nests in walls, or in tubes in the earth, in which the eggs are laid with a store of food for the larvæ. But the majority are social, living in well-organized communities. Some, however, never build nests for themselves but deposit their eggs in the nests of other bees; they are sometimes called parasitic bees. The familiar bumblebee makes its nest underground, and the eggs are laid amidst a store of honey and pollen, on which the larvæ feed. Only the queen bee or fertile female survives the winter. In the spring she seeks a hole in the ground and there deposits some pollen she has gathered, and lays a number of eggs; these develop into infertile females. Thereafter the only

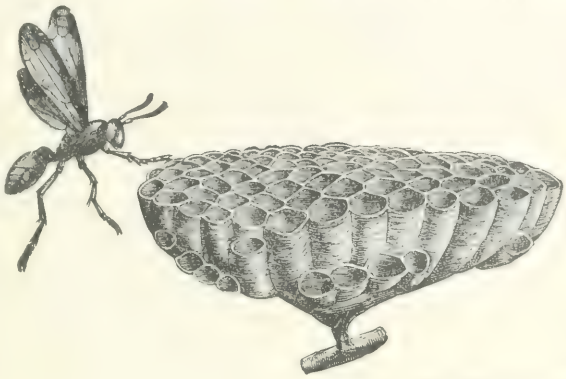


FIG. 228. *Polistes tepidus*, wasp and nest. (After Shipley and MacBride.)

FIG. 229. *Apis mellifica*, the honey bee. 1, worker; 2, queen bee; 3, drone. (After Shipley and MacBride.)

work of the queen consists in egg-laying, the infertile females or workers collecting pollen for food and caring for the young. In the early autumn some males or drones and some fertile females or queens are hatched from the eggs; then some of the queen bees, after being fertilized, hibernate and the others die.

The true honey bees make their nests in hollow trees, or when domesticated in artificial hives. There the workers, which again are sexually immature females, make the hexagonal cells of wax for the development of the larvæ and for storing the food supply of honey. All the eggs are laid by one female, the queen, who sometimes lays more than three thousand in a single day, and as many as a million in the course of a year. The eggs which are to develop into male bees or drones are unfertilized, and they are few, for the drones exist only shortly after coming out of the pupal stage, when the bees swarm and the queen is fertilized and a new colony is started; any drones still living in the hives in the autumn are killed by the workers, who alone with the queen live through the winter. The workers generally live only a number of months; the queen may live four or five years, and if the queen in a colony is accidentally killed or lost, a larva destined to become a worker may be made to develop into a queen by being fed with a particularly rich food supply by the workers.

The relation between the orders of the condensed classification just given and of the more extended classification will be seen from the following table: —

| Condensed Classification | | Extended Classification | |
|---|---|---|---|
| Order | | Order | |
| I. | Thysanura | I. | Thysanura. |
| | | II. | Ephemerida. |
| | | III. | Odonata. |
| | | IV. | Plecoptera. |
| II. | Pseudoneuroptera | V. | Isoptera. |
| | | VI. | Corrodentia. |
| | | VII. | Mallophaga. |
| | | VIII. | Physopoda. |
| III. | Orthoptera | IX. | Euplexoptera. |
| | | X. | Orthoptera. |
| IV. | Hemiptera | XI. | Hemiptera. |
| | | XII. | Neuroptera. |
| V. | Neuroptera | XIII. | Mecoptera. |
| | | XIV. | Trichoptera. |
| VI. | Lepidoptera | XV. | Lepidoptera. |
| VII. | Diptera | XVI. | Diptera. |
| | | XVII. | Siphonaptera. |
| VIII. | Coleoptera | XVIII. | Coleoptera. |
| IX. | Hymenoptera | XIX. | Hymenoptera. |

The more common or popular names of some of the representatives of these nineteen orders may be tabulated thus: —

| Order | | |
|---|---|---|
| I. | Thysanura. | Springtails, bristletails, fish moths. |
| II. | Ephemerida.[1] | May flies. |
| III. | Odonata.[2] | Dragon flies. |
| IV. | Plecoptera.[3] | Stone flies. |
| V. | Isoptera.[4] | Termites or white ants. |
| VI. | Corrodentia.[5] | Psocids, book lice. |
| VII. | Mallophaga.[6] | Sheep ticks, bird lice. |
| VIII. | Physopoda.[7] | Thrips. |
| IX. | Euplexoptera.[8] | Earwigs. |
| X. | Orthoptera. | Grasshoppers, crickets, cockroaches. |
| XI. | Hemiptera. | Lice, bugs, plant lice. |
| XII. | Neuroptera. | Ant-lions, hellgramite flies. |
| XIII. | Mecoptera.[9] | Scorpion flies. |
| XIV. | Trichoptera.[10] | Caddice flies. |
| XV. | Lepidoptera. | Moths, skippers, butterflies. |
| XVI. | Diptera. | Flies. |
| XVII. | Siphonaptera.[11] | Fleas. |
| XVIII. | Coleoptera. | Beetles. |
| XIX. | Hymenoptera. | Ants, wasps, bees. |

[1] Ephemerida, Gr. *ἐφήμερος*, living but a day.
[2] Odonata, Gr. *ὀδών*, tooth.
[3] Plecoptera, Gr. *πλέκος*, plaited, and *πτερόν*, wing.
[4] Isoptera, Gr. *ἴσος*, equal, and *πτερόν*, wing.
[5] Corrodentia, Lat. *corrodere*, to gnaw.
[6] Mallophaga, Gr. *μαλλός*, wool, and *φαγεῖν*, to eat.
[7] Physopoda, Gr. *φυσάω*, to blow up, and *πούς*, foot.
[8] Euplexoptera, Gr. *εὖ*, well, *πλέκω*, to fold, and *πτερόν*, wing.
[9] Mecoptera, Gr. *μήκος*, length, and *πτερόν*, wing.
[10] Trichoptera, Gr. *θρίξ*, hair, and *πτερόν*, wing.
[11] Siphonaptera, Gr. *σίφων*, tube, and *ἄπτερος*, wingless.

# CHAPTER VIII

## TYPE VI. MOLLUSCA

The Mollusca (Lat. *mollis*, soft) include those animals called popularly shellfish, such as snails, clams, oysters, and scallops, and in addition the slugs, squids, and cuttlefish. Despite this great variety of form, these animals merely present modifications of a common plan or type, so that the group as it stands to-day is pretty characteristic. Its position in the system of classification is very doubtful, however; the fact that we take it up at this point does not mean that it is more highly organized than the Arthropoda, or even than the Annelida; this is merely a convenient place to consider the group.

The Mollusca are bilaterally symmetrical animals, though a torsion of some parts may render the adult more or less asymmetrical. There is no evidence of segmentation in the adult, and so there may be some reason for placing the type below the segmented animals. There are no jointed appendages. The body is soft and moist; on the ventral side is a structure, called the foot, which is the chief organ of locomotion, but undergoes great modifications in the different groups. The body is usually more or less completely covered with a shell, either univalve or bivalve; this shell is lined by a fold of the skin, called the mantle, which hangs about the body, and the glands in the mantle secrete the shell, which consists chiefly of calcium carbonate. The space between the mantle and the body-wall of the animal is the mantle cavity. Often the shell can be seen to consist of three parts: a thin brown layer on the outside, which is chitinous; a much thicker middle layer, which is limy; and an inner lining, which is the pearly or nacreous layer, beautifully iridescent. With the exception of the land snails and slugs the members of this order are aquatic, some living in fresh water,

the majority in salt water. The organs of respiration are therefore gills as a rule, though they have very diverse forms in the different classes; in the terrestrial Mollusca there is a sort of lung.

There are several sets of special sense organs, notably tentacles, which usually serve as organs of touch, olfactory organs, otocysts, and very frequently eyes, which in some genera attain a very high degree of development. Of the internal organs we need merely note the nervous system, which is formed on rather a different type in most cases from that in the Annelida and Arthropoda. Typically there is a pair of cerebral ganglia in the head, or dorsal to the œsophagus; a second pair, one on each side of the œsophagus, the pleural ganglia; a pair in the foot, the pedal; and a pair in the region of the viscera, the visceral ganglia. The two ganglia in each pair are connected by nerve fibers called commissures, and each of the three last pairs is connected with the cerebral ganglia by means of nerve fibers called connectives. While reproduction is always sexual, hermaphroditism is very common, and the single germ gland then present is called the ovotestis. The development often takes place through a larva, which at first resembles the trochosphere of the Polychæta, and is usually provided with a delicate shell. The Mollusca are divided into five classes.

## CLASS I. AMPHINEURA

The Amphineura (Gr. *ἀμφί*, on both sides, and *νεῦρον*, nerve) are marine Mollusca with complete bilateral symmetry and a rather elongated body; the mouth is anterior, the anus posterior. The nervous system has no definite ganglia, and there are few sense organs. The class is divided into two readily distinguishable orders.

### Order 1. Solenogastres

The Solenogastres (Gr. *σωλήν*, groove, and *γαστήρ*, belly) live in the sediment at the bottom of the ocean, generally at considerable depths (Fig. 230). They are more or less cylindrical, vermiform animals, ordinarily from two to five or six centimeters long, without any shell, but with calcareous spicules

in the integument. On the ventral side of the body is a longitudinal groove, in which a narrow ciliated ridge is generally present and corresponds to the foot of other Mollusca. At the posterior end of the body there is generally a pair of gills near the anus. With the exception of one genus they are hermaphroditic. The order presents both primitive and degenerate characteristics.

FIG. 230. *Proneomenia sluiteri*, one of the Solenogastres. Lateral aspect above, ventral aspect below; natural size about ten centimeters long. (From Lang's Comparative Anatomy.)

### Order 2. Placophora

The Placophora (Gr. πλάξ, plate, and φορέω, to bear) are represented by the chitons (Figs. 231 and 232). The most striking external feature of these animals is the shell on the dorsal side of the body, which consists of eight over-

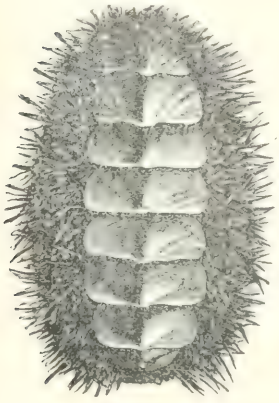


FIG. 231. *Chiton spinosus*, dorsal aspect. (From the Cambridge Natural History.)

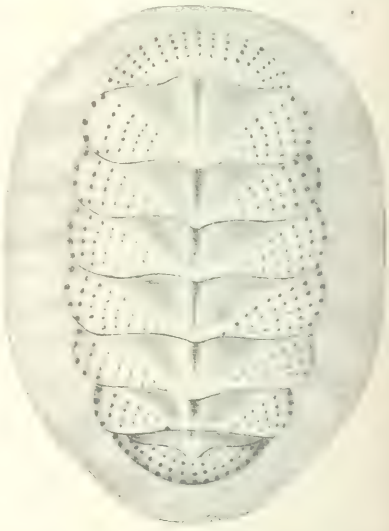


FIG. 232. *Chiton*, showing the eight overlapping plates of the shell. (After Prêtre, from Lang's Comparative Anatomy.)

lapping plates, forming a single antero-posterior series. This enables them to roll up into a ball and thus protect the soft parts of the body, which lie on the ventral surface. Projecting beyond the edges of the row of plates on all sides is the mantle, and on the ventral side of it lie the gills, sometimes forming a complete row around the body, sometimes confined to the posterior region. The foot on the median ventral surface of the body is sometimes narrow, but usually presents a broad, flat surface, extending from the mouth to the anus, and serves for creeping. In the mouth is a tongue, or odontophore, whose surface is covered with sharp chitinous teeth; a similar structure is found in many other Mollusca and is called technically the radula or lingual ribbon (Fig. 233). Organs of special sense are for the most part entirely wanting or very rudimentary. The Chitons are chiefly confined to the shores of the ocean, and the different species vary greatly in size.

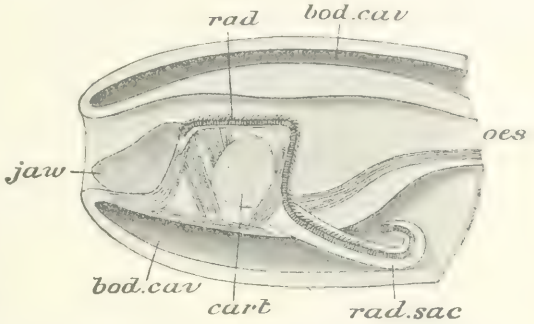



FIG. 233. *Triton nodiferus;* diagrammatic longitudinal vertical section of buccal or mouth cavity. *bod.cav*, body-cavity; *cart*, cartilage of odontophore; *jaw*, right jaw; *oes*, œsophagus; *rad*, radula; *rad.sac*, radula sac. (After Parker and Haswell.)

## CLASS II. GASTROPODA

The Gastropoda (Gr. γαστήρ, stomach, and πούς, foot) comprise the snails, slugs, limpets, and many others less familiar. The foot is generally long, with a broad, flat sole for creeping. There is usually a head more or less sharply marked off from the rest of the body. It bears one or two pairs of tentacles and sometimes a proboscis with the mouth at its tip; there is usually a pair of eyes on the head, sometimes on the tips or sides of a pair of tentacles, sometimes sessile, on the surface of the head. The mouth is provided with a radula or lingual ribbon borne on the odontophore.

On the dorsal side of the body is the mantle, consisting of a single caplike fold of the integument lining the shell. In some groups there is no shell, in others it is a thin, delicate, chitinous structure, but usually it is hard, calcareous, with a pearly lining. The shape of the shell varies greatly, from a simple conical cap to a greatly twisted spiral. The shell is generally large enough so that the foot and head can be completely withdrawn inside, and in some groups there is a flat, chitinous plate attached to the foot, which completely closes the aperture to the shell when the foot and head are within; this plate is called the operculum.

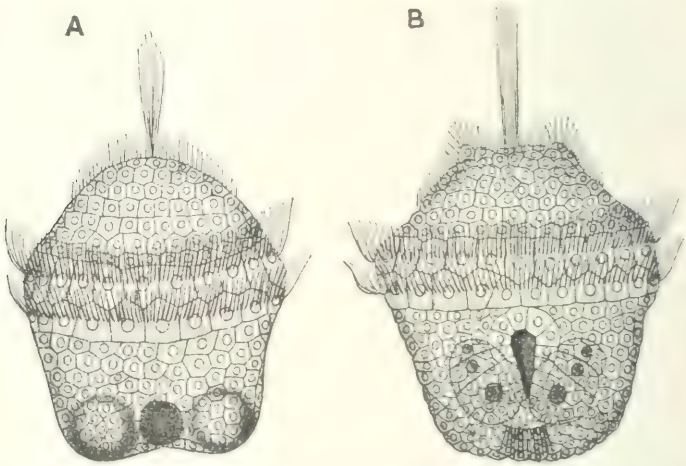



FIG. 234. *Patella*, a limpet; trochosphere larvæ in different stages. A, with circular blastopore and two foot elevations; B, with elongated blastopore and two mesodermal bands. (After Patten, from Parker and Haswell's Text-book.)

The mantle cavity contains one or two gills in the aquatic Gastropoda, and receives the anus and the openings from the excretory and reproductive organs; in the male it contains the copulatory organ, which is generally well developed. In the terrestrial genera the mantle cavity is transformed into a sort of lung or respiratory chamber.

Excepting the head and the foot, the body is to a considerable degree asymmetrical. The development is attended by the formation of larvæ; the first stage is a trochosphere (Fig. 234), which is succeeded by the veliger (Fig. 235), in which a ciliated membrane or velum is present on the head and forms the organ

of locomotion. A shell is present in the larva, although it may be lost in the adult.

The majority of the Gastropoda are marine, though some live on land and some in fresh water. They occur for the most part crawling about on the sea bottom, although some live near the surface and so are pelagic. They have been taken at all depths to about six thousand meters, it is said. Their food varies much; some feed entirely on plants, some on dead animal matter, some on living animals. Some species have glands connected with the mouth, which secrete a weak sulphuric acid, from two to four

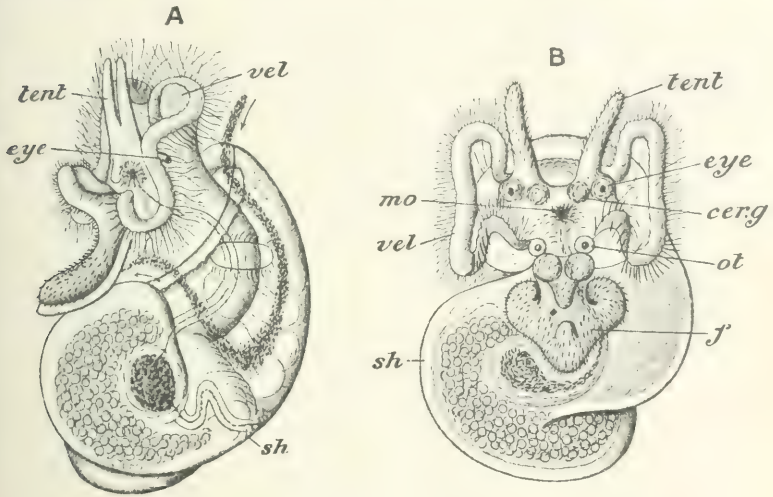



FIG. 235. *Vermetus;* larvæ in the veliger stage. A, lateral aspect; B, ventral. *cer.g*, cerebral ganglia; *eye*, eye; *f*, foot; *mo*, mouth; *ot*, otocyst; *sh*, shell; *tent*, tentacles; *vel*, velum. (After Lacaze-Duthiers, from Parker and Haswell's Text-book.)

per cent. With this they soften a spot on the shell of some other mollusc and then bore a smooth, circular hole with the radula and through this feed on the animal within. The Gastropoda may be divided into three orders.

### Order 1. Prosobranchia

The Prosobranchia (Gr. *πρόσω*, toward the front, and *βράγχια*, gills) include almost all the marine Mollusca which have a univalve shell and all the fresh-water snails; thus the order is largely marine, and a shell is very rarely absent. In this group

the sexes are separate as a rule. A protrusible proboscis is often present, and frequently the edge of the mantle in front is drawn out into an elongated groove or tubular structure, called the siphon. By means of the siphon water may be drawn into the mantle cavity. An operculum is often present, attached to the dorsal side of the foot. In the mantle cavity there is usually only a single gill, and in most cases a well-developed penis in the male.

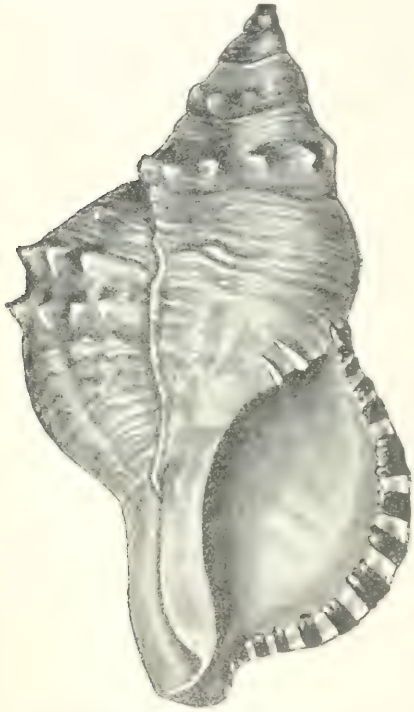


FIG. 236. *Triton nodiferus*, shell, natural size; from New Zealand. (After Parker and Haswell.)

The shells vary from simple conical caps to the most elaborately coiled spirals (Figs. 236 and 237), and may be smooth and polished, or roughened with ridges, or provided with long spines; the colors are often very beautiful in tropical shells and some have pearly linings. There are some species in which the spiral is so loosely wound that adjacent coils are not in contact with one another (Fig. 238), so that the shells closely resemble the calcareous tubes of some of the polychætous Annelida. Most of the spiral shells have the coil running from left to right; such shells are called dextral in distinction from those running toward the left, which are called sinistral. The limpets are familiar examples of conical shells; they constitute a conspicuous article of food in parts of Europe where they are abundant. Sometimes the shell is closed at the tip, sometimes there is an opening shaped like a keyhole, hence the name keyhole limpets (Fig. 239). The slipper limpets (*Crepidula fornicata*) (Fig. 240) are common, attached to other shells or to

kingcrabs; they have a sort of shelf on the inner side of the shell. The sea ears, or abalone shells as they are called in California, have a beautifully iridescent, pearly lining. The row of holes in the shell is produced by the edge of the mantle, as the shell increases in size. The strength with which the limpets and sea ears can fasten themselves to rocks and other objects is remarkable.

A snail of some economic importance on the eastern coast of the United States is the drill snail, *Urosalpinx cinerea*, which bores holes in the shells of oysters and then devours the animal. The whelks are common in Europe and America along the northern Atlantic coasts, where they bury themselves in the sand; they are largely eaten in England. The

FIG. 237. *Triton nodiferus;* median longitudinal section of shell. (After Parker and Haswell.)

FIG. 238. *Vermetus lumbricalis*, a [illegible] spiral shell. (From Brehm's Thierleben.)

eggs are laid in yellow, hemispherical capsules, half a centimeter or more in diameter, which adhere together in spherical balls about ten centimeters in diameter (Fig. 241); they are called sea corn by the New England fishermen. A large snail, *Fulgur carica*, has even more conspicuous egg capsules (Fig. 242). They consist of disc-shaped cases with a circular thin spot at one margin, marking the point of exit of the embryos, and at the opposite diameter are attached to a stalk, likewise formed by the snail, which may be from sixty centimeters to nearly a meter in length.

FIG. 239. A keyhole limpet; shell seen from above. (Drawn from specimen.)

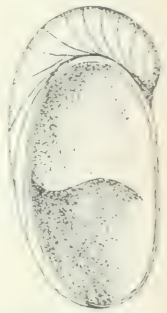


FIG. 240. *Crepidula*, a slipper limpet. (Drawn from specimen by the author.)

The most abundant snail along the New England coast today is the periwinkle, *Littorina littorea*, which some years ago was introduced from England into Halifax, whence it spread pretty rapidly southward; in England it is a great article of food. Along the sandy shores of New England the so-called sand collars are very abundant in summer time; these are simply masses of eggs, to which the sand adheres, which have been laid by a very large snail, *Natica heros*, whose shell sometimes attains a diameter of eight centimeters; its

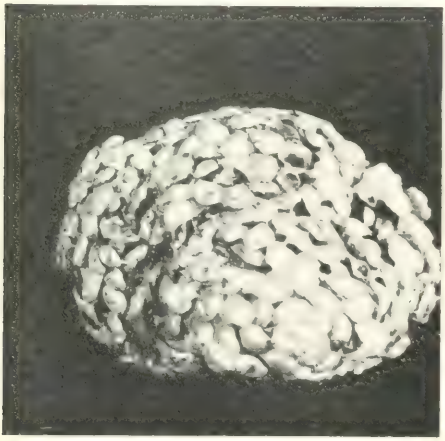


FIG. 241. Mass of egg capsules of a marine snail, *Buccinum*; reduced about one half. (Photographed from specimen by the author.)

foot is capable of swelling to almost twice that diameter. It feeds largely on clams, boring a hole in the shell very much as Urosalpinx attacks the oyster. Certain tropical snails, notably the genus Conus, are said to have a poisonous bite, but probably not fatal except to small animals. Another group of tropical Gastropoda is interesting because the shells, consisting of layers of different colors, are used in the manufacture of cameos. They belong to the family Cassidæ, called commonly helmet shells; the one most used is *Cassis madagascarensis*.

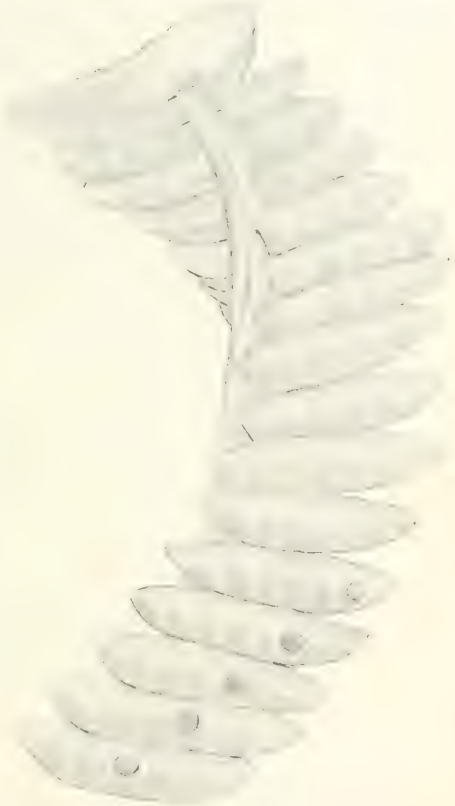


FIG. 242. *Fulgur*. Portion of egg capsules, natural size; they decrease in size toward one end of the string, which is frequently over thirty centimeters long. (Drawn from specimen.)

Finally, we include in this order the curious transparent Mollusca called the Heteropoda, common in tropical waters (Fig. 243). The body is more or less cylindrical and the foot is compressed laterally into a sort of fin, by means of which the animal swims. On the dorsal side of the body the viscera may be found in a small hump inclosed in a simple shell, or the shell may be entirely absent. They are jellylike animals, pelagic, and often attain a length of from fifteen to twenty centimeters.

### Order 2. Opisthobranchia

The Opisthobranchia (Gr. ὀπίσθιος, behind, and βράγχια, gills) are all marine and include the sea slugs and the sea

butterflies. In some of them shell, mantle, and gills are well developed, in others they are entirely absent. All the members of the order are hermaphroditic, but a penis is present and cross fertilization takes place. The sea slugs, known technically as the Nudibranchia (Lat. *nudus*, naked, and *branchia*, gill), naked-

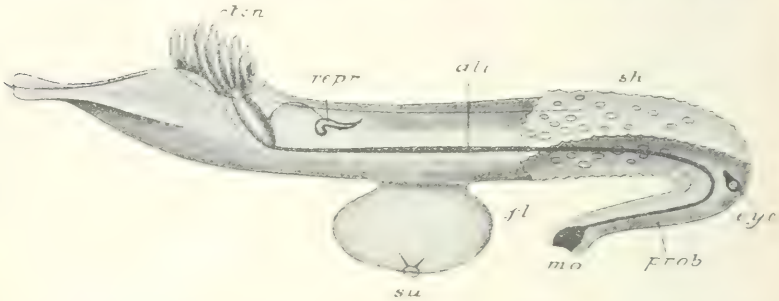



FIG. 243. *Pterotrachea scutata*. *ali*, alimentary canal; *cten*, gills; *eye*, eye; *fl*, foot; *mo*, mouth; *prob*, proboscis; *repr*, reproductive gland; *sh*, shell; *su*, sucker. (After Parker and Haswell.)

gilled, generally have an elongated body with no shell or mantle, and the foot provided with a broad sole for creeping (Fig. 244); but some pelagic genera have no foot, some have a mantle containing calcareous spicules, and some have a delicate shell. Many have adaptive gills in place of the true gills; these are fingerlike

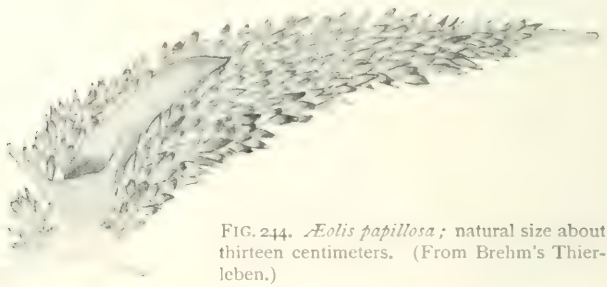


FIG. 244. *Æolis papillosa*; natural size about thirteen centimeters. (From Brehm's Thierleben.)

or leaflike processes very variously arranged on the dorsal side of the body; their coloring is often extremely beautiful.

In size they vary greatly from a few millimeters to some thirty centimeters in one tropical genus. One genus lives as a parasite in one of the Holothuroidea; the adult has lost all its Molluscan characteristics and resembles a worm, but the larvæ are of the

usual veliger type. The sea butterflies, or Pteropoda, are minute pelagic animals, very transparent, and rarely attaining a length of two or three centimeters. The foot is at the anterior end of the body, and is flattened out in two lateral folds or winglike structures, by means of which the animal swims (Fig. 245). In some a delicate, transparent shell is present, in others there is no shell.

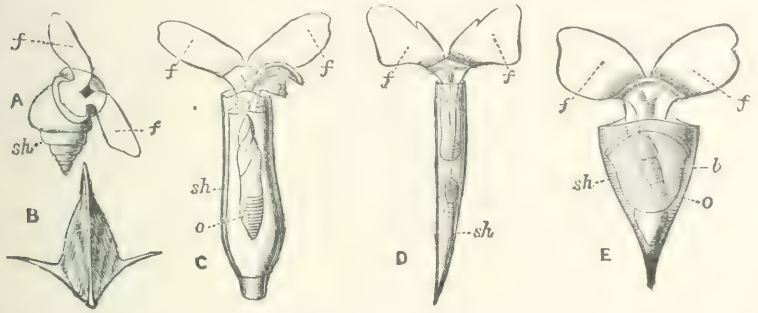



FIG. 245. Various shell-bearing **Pteropoda**. *f*, fin; *l*, liver; *o*, ovary; *sh*, shell. (After Souleyet, from Parker and Haswell's Manual.)

## Order 3. Pulmonata

The Pulmonata (Lat. *pulmo*, lung) are terrestrial or freshwater Gastropoda without gills, and having the mantle cavity modified into a sort of lung or respiratory chamber. Those species that live in the water must necessarily come to the surface occasionally to change the air in their lungs; but some living at the bottom of deep lakes have the chamber filled with water, and thus use it as they would gills. The edge of the mantle is fused with the body wall except at one point, usually on the right side of the body, which serves as the respiratory pore or opening into the mantle cavity. Some have a large shell, usually dextral, others a very rudimentary shell, and some no shell at all. There is no operculum to close the shell as in the Prosobranchia; but during the dry season or at the approach of winter the animal secretes a temporary parchment-like membrane which protects it from desiccation. The mouth is provided with a radula as in many other Mollusca. All the Pulmonata are hermaphroditic, and a few species are viviparous.

Of the aquatic genera, Limnæa (Fig. 246) is one of the commonest in our Northern states; it has a sharply pointed shell, and is a host for the larval stages of the flukeworms, already described under the Trematoda. Planorbis has a flat spiral in a single plane, and little fresh-water limpets occur, very like the salt-water species. The terrestrial Pulmonata all have two pairs of tentacles, with the eyes situated at the tips of the posterior pair. A few of them, mostly tropical species, are carnivorous, feeding on worms and on other Pulmonata, but the majority are plant-eaters. The largest family of land snails is the Helicidæ, which is very widely distributed; in the tropics their shells are often very brilliantly colored. Two species, *Helix pomatia* (Fig. 247) and *Helix aspersa*, are largely eaten in Europe. In Brazil there is a very large species sold in the markets, whose shell measures fifteen centimeters in length.

FIG. 246. *Limnæa stagnalis*, common fresh-water snail. (From Brehm's Thierleben.)

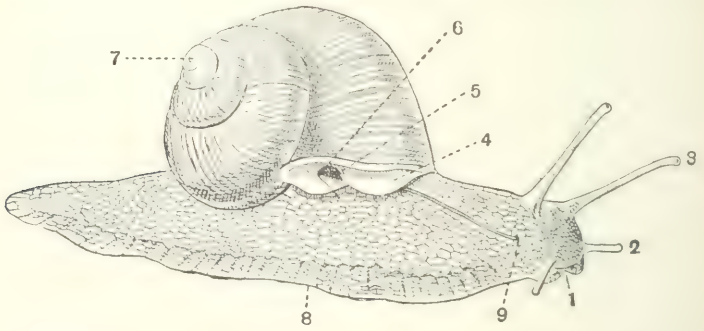



FIG. 247. *Helix pomatia*, a land snail. 1, mouth; 2, anterior tentacles; 3, eye tentacles; 4, edge of mantle; 5, respiratory pore; 6, anus; 7, apex of shell; 8, foot; 9, genital opening. (After Shipley and MacBride.)

But the largest known species is found in Africa living on trees, and having a shell twenty-five centimeters long; the eggs of this species are very large, and, as in some other large species, are laid in calcareous shells.

In the slugs (Fig. 248) the shell is either very rudimentary or entirely absent. The mantle is present, however, like a cap on the dorsal side of the body, and at one side, usually the right, is the respiratory pore. The head bears two pairs of tentacles, and eyes as in the land snails. The largest species in the United States measures about ten centimeters, but in other countries there are larger species. They are chiefly nocturnal in habit, and feed upon vegetables. In Europe they have become on this account veritable pests, but in America they do no serious damage. As they crawl along, a gland at the anterior end of the foot emits a secretion of mucus, thus making a smooth road for the foot; and some slugs, after ascending trees, fasten this mucus to a branch, and then let themselves down by stretching it out into a thread, very much as a spider descends.

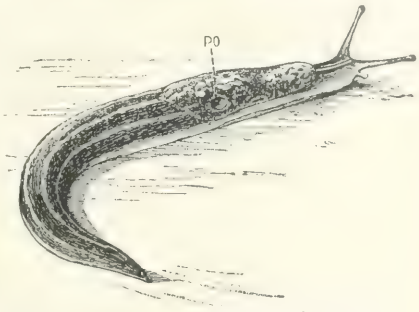



FIG. 248. *Limax*, a slug. *PO*, pulmonary aperture. (From the Cambridge Natural History.)

## CLASS III. SCAPHOPODA

The Scaphopoda (Gr. σκάφος, digging, and πούς, foot), a small group consisting of the elephant-tooth shells, are important because forming a sort of connecting link between the preceding class and the succeeding. They are marine Mollusca, living in the sand or mud at depths of from twenty to two hundred meters, with slightly curved, tubular shell (Fig. 249), open at both ends and larger at the ventral than at the dorsal end. The animal itself is strictly bilaterally symmetrical, and is provided

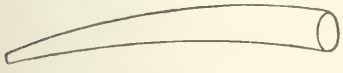


FIG. 249. *Dentalium*. Outline of shell showing general shape and the larger circular opening. (Drawn from specimen.)

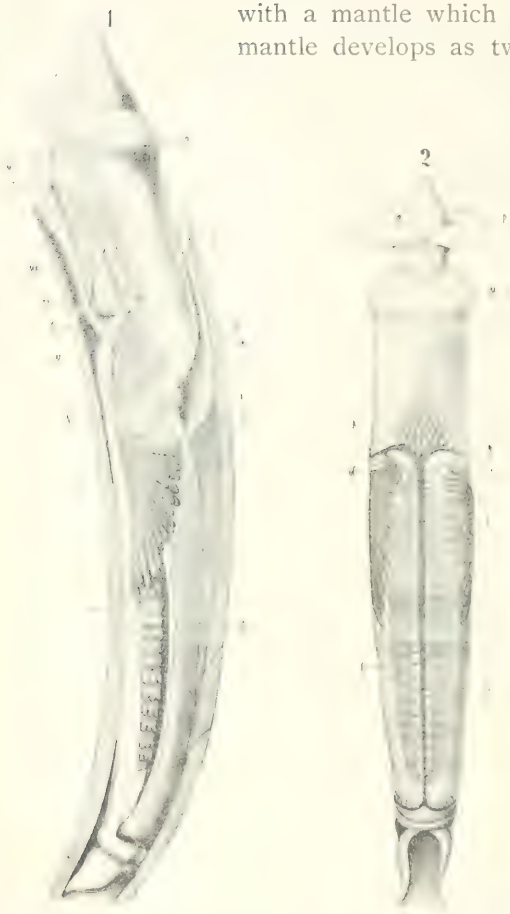



FIG. 250. *Dentalium entalis*. Anatomy; enlarged. 1, shell and mantle cut away from the right side of the body; 2, animal removed from shell and viewed from ventral side. *A*, anus; *G*, germ-gland; *GC*, cerebral ganglia; *GO*, genital opening; *GP*, pedal ganglion; *GS*, sympathetic ganglia; *I*, intestine; *K*, respiratory network; *L*, liver; *M*, mantle; *MK*, oral proboscis; *Mu*, muscle; *N*, excretory organ; *P*, foot; *SD*, dorsal blood-sinus; *SK*, pharynx; *SV*, ventral blood-sinus; *T*, tentacles; *TT*, tentaculiferous lobe. (Photographed from a Leuckart-Nitsche wall chart by the author; permission of Dr. C. Chun.)

with a mantle which lines the shell. This mantle develops as two folds, a right and a left on the dorsal side of the body, and these folds later fuse on the ventral side; this condition shows a relationship to the succeeding class. The mouth is at the tip of a process called the proboscis, and is provided with a radula, in this respect resembling the Gastropoda. On each side of the proboscis is a tuft of slender tentacular outgrowths, which may serve in securing food and also in respiration, as there are no special organs of respiration. The foot is nearly cylindrical, with a rounded conical end, and the sexes are separate. The shells vary in length from two or three to ten centimeters; Dentalium (Fig. 250) is the commonest genus.

## CLASS IV. LAMELLIBRANCHIA OR PELECYPODA

The Lamellibranchia (Lat. *lamella*, leaf, and *branchia*, gill), or Pelecypoda (Gr. πέλεκυς, hatchet, and πούς, foot), sometimes

called the Acephala (Gr. ἀ, without, and κεφαλή, head), as well as several other names, include all the Mollusca with bivalve shells. They are mostly marine, although some genera live in fresh water. The body of the animal is generally more or less completely inclosed in the shell, the two valves lying on the right and the left sides respectively and joined on the dorsal side of the body by a hinge.

The shell generally shows a series of concentric markings or ridges, which indicate successive stages of growth, and are arranged concentrically about a point on the dorsal side, called the umbo; this is sometimes in the middle of the dorsal side, but usually nearer the anterior end (Fig. 251). The shell is

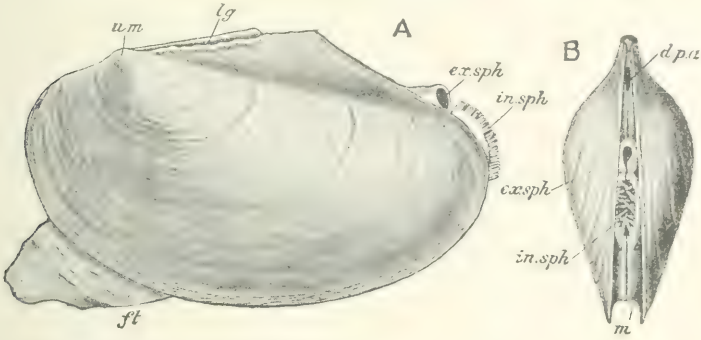



FIG. 251. *Anodonta cygnea*, a fresh-water mussel. A, from the left side; B, from the posterior end. *d.p.a*, dorsal pallial aperture; *ex.sph*, exhalant siphon; *ft*, foot; *in.sph*, inhalant siphon; *lg*, ligament; *m*, mantle; *um*, umbo. (After Howes, from Parker and Haswell's Manual.)

sometimes further marked by radiating elevations, flutings, or ribs, and in some species is provided with spines of considerable length. The tropical shells are often very brilliantly colored.

After the soft parts of the body have been removed, the interior of the shell, which usually has a pearly lining, exhibits some characteristic markings (Fig. 252). Near the edge is a line running parallel with it, the pallial line, which marks the attachment of muscles in the mantle. In some shells this line does not follow the edge at the posterior end of the shell, but makes a deep indentation called the pallial sinus, where the muscles of a structure called the siphon are attached. Further, we find one or two very smooth spots, which mark the attachment of the strong

muscles which hold the two valves of the shell together. These are called the adductor muscles, and there may be an anterior and a posterior, or only a large one, which then corresponds to the posterior muscle. These muscles serve to close the valves of the shell, which are opened by an elastic ligament attached to them at the hinge.

The mantle consists of two lobes, a right and a left, attached to the dorsal side of the body and completely lining the two valves of the shell. It is the mantle which forms the pearls used as ornaments. The edges of the mantle may be entirely free from each other, but frequently there are two slight depressions at the posterior end in each mantle, so that when they are approximated, two slit-like openings are left. Through the ventral opening the water is drawn into the mantle cavity and forced out through the dorsal. In other cases the edges of the mantle are fused at the posterior end, leaving two permanent slits, and in some cases this fusion passes farther and farther toward the anterior end, until the mantle forms essentially a sac inclosing the whole body with only two openings at the posterior end, and one at the anterior end through which the foot may be protruded. Further, the edges of the mantle about the posterior openings may be drawn out into two long tubes or siphons, the water flowing in through the ventral and out through the dorsal. The two siphons may remain distinct or the two may fuse, the tubes, however, remaining separate, and one siphon may be longer than the other (Fig. 253).

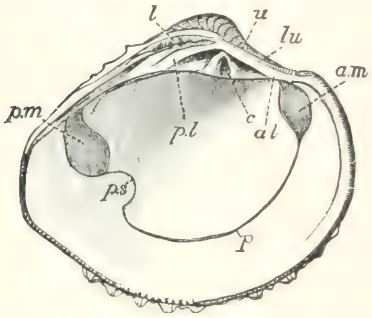



FIG. 252. *Venus gnidia.* Inner surface of left valve. *al*, anterior lateral tooth; *a.m*, anterior adductor impression; *c*, cardinal teeth; *l*, ligament; *lu*, lunule; *p*, pallial line; *p.l*, posterior lateral tooth; *p.m*, posterior adductor impression; *p.s*, pallial sinus; *u*, umbo. (From the Cambridge Natural History.)

The body lies within the mantle cavity. It is strictly bilaterally symmetrical and is usually considerably compressed laterally. The gills lie between the body wall and the mantle, and are usually leaflike plates, two on each side of the body attached near the dorsal side (Fig. 254). Their surfaces, like the inner

surface of the mantle, are richly ciliated. There is no distinct head; on each side of the mouth are two delicate folds, the

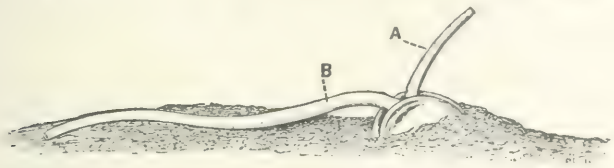



FIG. 253. *Scrobicularia piperata*, in its natural position, partly buried in the sand. *A*, exhalant siphon; *B*, inhalant siphon. (From the Cambridge Natural History.)

labial palps, which assist in carrying food to the mouth. On the ventral side of the body at the anterior end is the foot, a muscular structure, often laterally flattened with a pointed extremity; it varies very greatly in size and shape in different species; in some it is very much reduced or even entirely

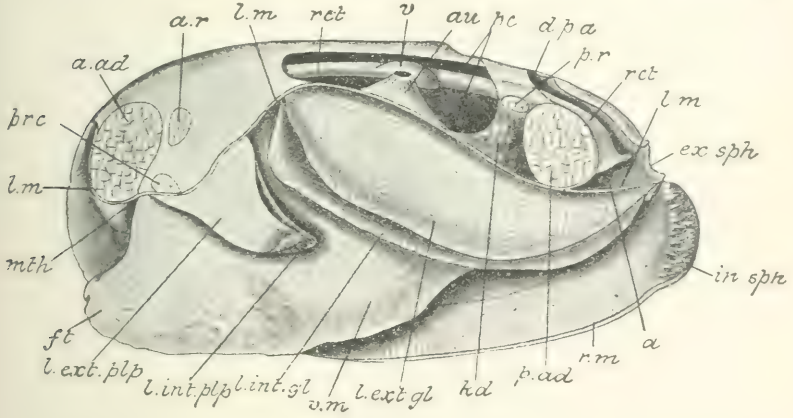



FIG. 254. *Anodonta cygnea*. The left valve of the shell, and the greater part of the left mantle lobe, removed. *a*, anus; *a.ad*, anterior adductor; *a.r*, anterior retractor; *au*, left auricle; *d.p.a*, dorsal pallial aperture; *ex.sph*, exhalant siphon; *ft*, foot; *in.sph*, inhalant siphon; *kd*, kidney; *l.ext.gl*, left external gill; *l.ext.plp*, left external labial palp; *l.int.gl*, left internal gill; *l.int.plp*, left internal labial palp; *l.m*, cut edge of the left mantle lobe; *mth*, mouth; *p.ad*, posterior adductor; *pc*, pericardium; *pr*, posterior retractor; *prc*, protractor; *rct*, rectum; *r.m*, right mantle lobe; *v*, ventricle; *v.m*, visceral mass. (After Parker and Haswell.)

wanting. Connected with the foot in some genera is a gland, the byssus gland, which secretes a substance forming threads, usually brownish in color, by means of which the animal attaches itself to other objects (Fig. 255). In some cases at least this attachment is not permanent, for the animal

can break away from its threads and form a new attachment elsewhere. Organs of special sense are variously present in different groups, in the form of palps and tentacles as tactile organs, eyes, situated on the edges of the mantle or the tip of the siphon, and otocysts. The alimentary canal terminates in an anus near the posterior adductor muscle. The sexes are usually separate, but sometimes united in one individual, and in the marine genera there is a larva resembling the trochosphere. The further classification of the Lamellibranchia is somewhat disputed. They are sometimes divided into two subclasses, the Asiphonia, those without a siphon, and the Siphoniata, those having a siphon. For convenience we may consider some of the more important members under these two groups, noting particularly some of economic importance. The oyster is one of the most important members of the class from this point of view. The edges of the mantle are not fused, there is no siphon, the foot is very rudimentary or entirely absent, and the two valves of the shell are of unequal size. The left valve is concave and attached to some foreign object, the right is smaller and flatter. They are hermaphroditic and reproduce in June and July. In Europe the species principally eaten are *Ostrea edulis* and *Ostrea angulata*. In America the most common is *Ostrea virginiana*, which occurs along the whole eastern coast from the Gulf of St. Lawrence to the Gulf of Mexico except on the eastern shores of New England. On the western coast of the United States two species which are eaten, occur. Oyster beds are now planted artificially. The eggs are often hatched in ponds of salt water, and the young oysters when they first attach themselves are called spat; later, when old enough to be transplanted to the shore beds, they are termed seed oysters. Our largest oysters are from ten to fifteen centimeters long; in

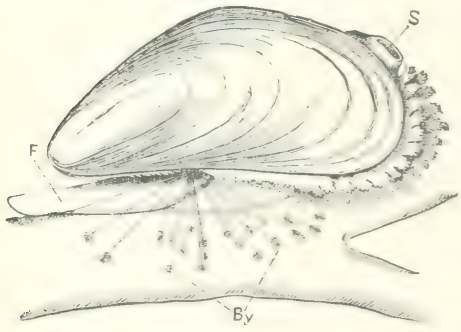



FIG. 255. *Mytilus edulis*. *By*, byssus, attached to a stone. (From the Cambridge Natural History.)

Japan some are said to attain a length of nearly a meter. The scallops, whose single large adductor muscle is the only part eaten, usually have numerous tentacles and variously colored eyes at the margins of the unfused mantle folds. They have a small foot, often with a byssus gland, and can swim rapidly by opening and closing the valves of the shell.

Of the mussels, the pearl mussel or oyster is the most valuable because of the pearls which its mantle secretes. The real pearl

FIG. 256. *Pholas*, a boring mussel in a cavity which it has excavated in a rock. (From Brehm's Thierleben.)

mussel, *Meleagrina margaritifera*, is found in almost all tropical waters; in the Orient it attains a length of from twenty to thirty centimeters, but in the West Indies and Gulf of Mexico it is smaller. The finest pearls come from the Gulf of Persia, while the most fishing is done off Ceylon. The divers go out in February, March, and April to the beds, which are usually at a depth of from eighteen to twenty meters; they fill nets with the oysters and then come to the surface, rarely remaining under

water more than sixty seconds. The animals are allowed to die, the soft parts washed away, and then the pearls are sought for: some, the finest, are free, others are attached to the shell and must be chipped off. Pearls are probably always secreted about some object, often a bit of sand, and are formed by many other bivalves, though of not so fine a quality as by the pearl oyster.

Of the other salt-water mussels, aside from those which form a chief article of food in many parts of Europe, there are the boring mussels, in which the body is greatly elongated, often having a very small shell. Some of these make cavities in stone as well as in wood (Figs. 256 and 257), such as *Lithodomus*

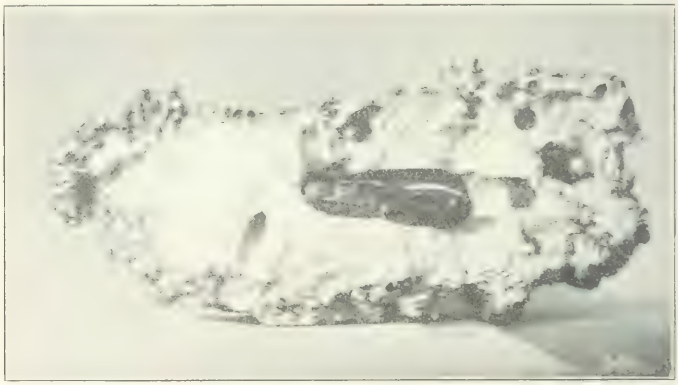


FIG. 257. Boring mussel in a fragment of limestone. (Photographed from a specimen obtained at Bermuda, by the author.)

*dactylus*. The borings in the columns of the temple of Serapis at Pozzuoli near Naples show the geologist the degree of submergence of these columns beneath the sea at one time. The fresh-water mussels which live in our ponds and rivers and brooks carry their young about in a sort of brood pouch in the gills. One species, *Margaritana margaritifer*, found in Europe and the United States, produces pearls of considerable value and often pink in color.

Of the Siphoniata or Lamellibranchia with the edges of the mantle fused posteriorly into a siphon, the edible species are the most familiar. The cockles, having greatly arched, swollen shells, are largely eaten in England. The common clam, *Mya arenaria*, is a very familiar article of food in our Eastern states.

The razor clams, of which *Ensis americana* is an example, with a greatly elongated shell, are also eaten, both here and in Europe, but they are not so abundant and are difficult to catch. The quahog, or cohog, or thick-shelled clam, *Venus mercenaria*, is very abundant from Mexico to Cape Cod and forms a common article of food; other species occur on our Western coast. It was from their shells that the Indians made their wampum.

All are carnivorous. The largest bivalve of this group is the *Tridacna gigas* of the Indian and Pacific oceans; the soft parts of such a clam may weigh ten kilos and the shell as much as two hundred and fifty kilos.

A boring mussel, the *Teredo navalis*, or shipworm and allied species, belong here. The Teredo (Figs. 258 and 259) bores tubes for itself in piles, logs lying in the water, and wooden vessels, until the structure crumbles under the slightest strain. Although thousands of these animals may be in the same piece of wood, their tubes

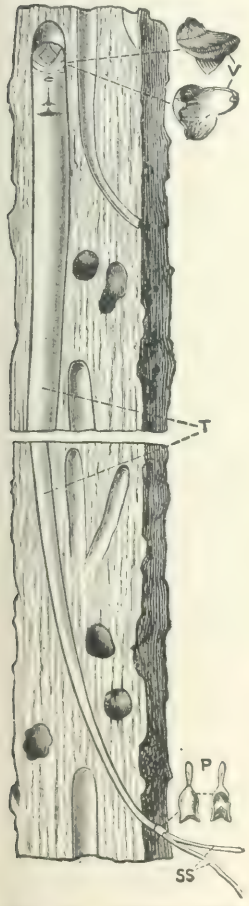



FIG. 258. *Teredo navalis*, natural size, in a piece of timber. *P*, pallets enlarged; *SS*, siphons; *T*, tube; *V*, valves of shell enlarged. (From the Cambridge Natural History.)

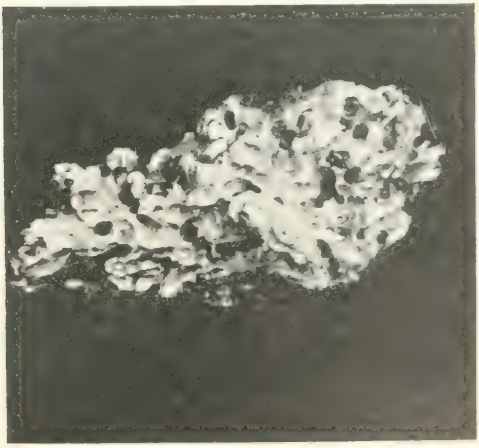


FIG. 259. *Teredo navalis*, the shipworm, ... mus... bores in wood; a fragment of very hard wood rid... with the tubes of this mollusk; the tubes are lined with a calcareous secretion. (Photographed from specimen by the author.)

never interfere with one another, but a thin partition of wood is always left between. They have done great damage to wharves in both Europe and America. Their tubes are sometimes as much as twenty-five centimeters in length and a centimeter in diameter. In the Philippines an allied genus occurs which bores in the sand only; the body is five centimeters in diameter and but little short of two meters long.

## CLASS V. CEPHALOPODA

The Cephalopoda (Gr. *κεφαλή*, head, and *πούς*, foot), while unquestionably belonging to the type Mollusca, constitute an isolated group without any close relationship to the other classes. They include such animals as the nautilus, octopus, cuttlefish, and squid, all exclusively marine, and found along the shore or swimming near the surface in the open ocean, or in the case of the larger species living at considerable depths. The body is bilaterally symmetrical, and there is a head marked off from the rest by a slightly narrower region or neck. This head has a circle of armlike processes, sometimes bearing tentacles, sometimes hooks, or suckers, and to be regarded as homologous with a part of the foot in other Mollusca. In the center of these tentacles is a depression, at the bottom of which lies the mouth. It is provided with two strong, chitinous jaws, resembling the beak of a parrot, and within is a typical radula. The head also bears a pair of eyes, usually very highly developed, as well as otocysts and often olfactory organs.

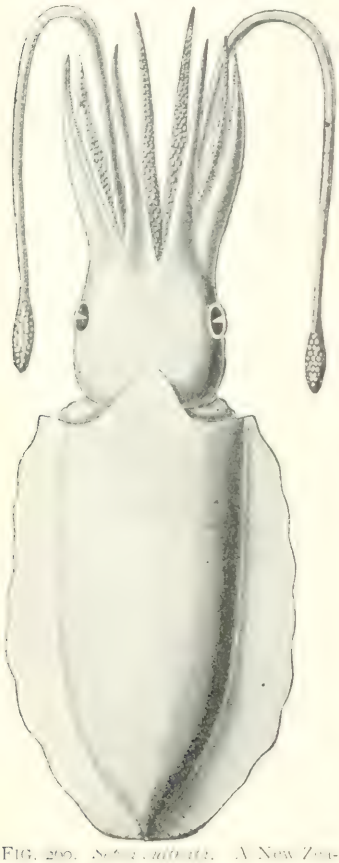


FIG. 209. *Nototodarus sloanii*. A New Zealand cuttlefish; dorsal aspect. (After Parker and Haswell.)

The portion of the body at the back of the head, often called the visceral hump, is homologous with the shell-bearing portion of the body of the Gastropoda, which is known by the same name. It is inclosed in the saclike mantle, which is attached along what is the upper side of the body when the animal is in its normal position (Fig. 260). The mantle cavity is open to the outside by a slitlike aperture surrounding the neck, and through this opening a funnel-like organ projects on the lower side of the body. The funnel is homologous with a portion of the foot of other Mollusca. Within the mantle cavity are the gills, either one or two pairs, and the openings of the posterior end of the alimentary canal, of the excretory and the reproductive organs (Fig. 261). When at rest or moving slowly, the water is drawn into the mantle cavity and forced out again through the slitlike opening referred to, by means of the alternate expansion and contraction of the walls of the mantle. But when the animal wishes to swim rapidly the siphon is brought into play. The water is drawn into the mantle cavity as usual; then the edge of the mantle is firmly locked to the body wall, — in some cases there is a special apparatus for this purpose consisting of a pair of corresponding elevations and depressions on the mantle and body wall respectively; thus the mantle cavity is closed and the water is forced out through the funnel, so that the body of the animal is projected backward. The funnel can be bent so as to force the water out in various directions, and thus the animal may move sidewise or even forward. Some Cephalopoda have fins at the sides or end of the body, which also assist in locomotion.

In a few cases there is an external shell; in most there is an internal shell which has come to occupy its present position through an overgrowth of the mantle; in some there is no shell whatever. In most species the integument contains numerous pigment cells or chromatophores, the size of which can be greatly changed, thus producing great variations in the color of the animals, especially as there are chromatophores of several colors. In this way remarkable plays of color are produced as the animals swim about. Some species also have a silvery or iridescent appearance.

Of the internal anatomy we may note two or three of the

most important characteristics. The nervous system exhibits a great concentration, all the chief ganglionic masses being grouped in the head about the œsophagus and inclosed in a

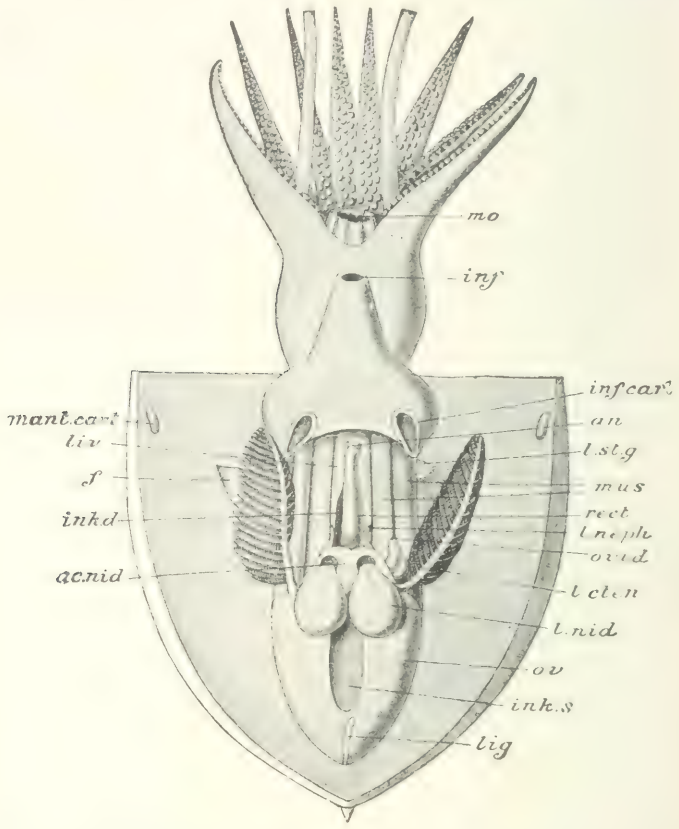
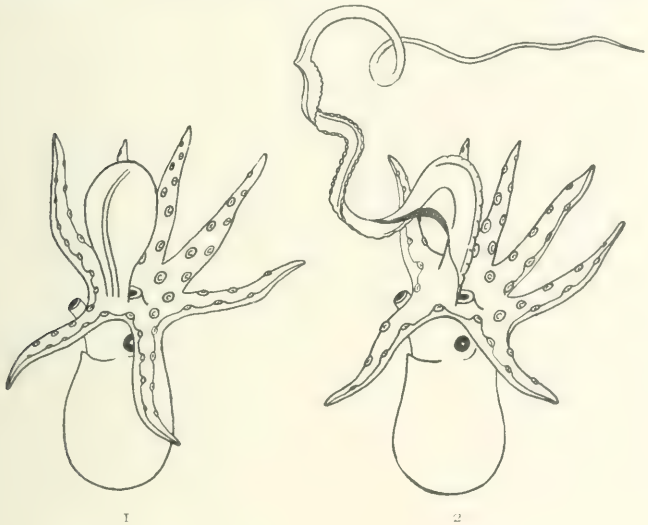



FIG. 261. *Sepia cultrata.* Female, posterior aspect, with contents of mantle cavity exposed by the division of its wall along the median line. *ac.nid*, accessory nidamental glands; *an*, anus; *f*, membrane attaching gill to wall of mantle cavity; *inf*, external opening of funnel; *inf.cart*, infundibular cartilage; *ink.s*, ink sac; *ink.d*, ink duct; *lig*, cut ligament passing from ovary to wall of mantle cavity; *liv*, liver; *l.cten*, left ctenidium or gill; *l.neph*, left nephridial aperture; *l.nid*, left nidamental gland; *l.st.g*, left stellate ganglion; *mant.cart*, mantle cartilage; *mo*, mouth; *mus*, neck muscles; *ov*, ovary; *ov.d*, oviduct; *rect*, rectum. (After Parker and Haswell.)

sort of internal skeleton of cartilage. In most of the Cephalopoda there is an ink gland, or ink sac, which generally opens into or near the terminal portion of the alimentary canal. When pursued or attacked by an enemy this ink or sepia is discharged

into the water, which is thus rendered opaque, and the animal has a chance to escape. The sexes are separate and there is no metamorphosis in development, so no larva is produced.

In some species a curious modification of one of the arms of the male occurs in connection with reproduction. This arm is inclosed in a swollen sac, which bursts and sets the arm free; this arm is called the hectocotylized arm (Fig. 262). Then in some way, not known, a sac filled with spermatozoa, called the spermatophore, becomes connected with this arm, which breaks



1 2

FIG. 262. *Argonauto argo*, male. 1, with hectocotylized arm in its sac; 2, protruded from sac; this arm contains the spermatophores or masses of spermatozoa; it eventually separates from the male, passes into the mantle cavity of the female, and there the eggs are fertilized. (After Müller.)

away from the body of the male and enters the mantle cavity of the female. When first discovered there it was thought to be a parasitic worm and was called Hectocotylus. There are large numbers of fossil Cephalopoda; the living species may be grouped in two subclasses dependent on the number of gills present.

## SUBCLASS I. TETRABRANCHIATA

The Tetrabranchiata (Gr. τετρα-, four, and βράγχια, gills) include a large number of fossil genera, but have only a single

living genus, the pearly or chambered nautilus (Fig. 263), which lives in the Indian and Pacific oceans. As the name of the group suggests, there are four gills, — two pairs. The lobes about the mouth, which represent a part of the foot, are not long and bear numerous slender tentacles. The funnel, likewise a part of the foot, is not a closed tube, but is open along the lower side, though the two edges may be approximated. The eyes are extremely simple in structure. The ink sac, present in most Cephalopoda, is wanting in the nautilus. The shell, which

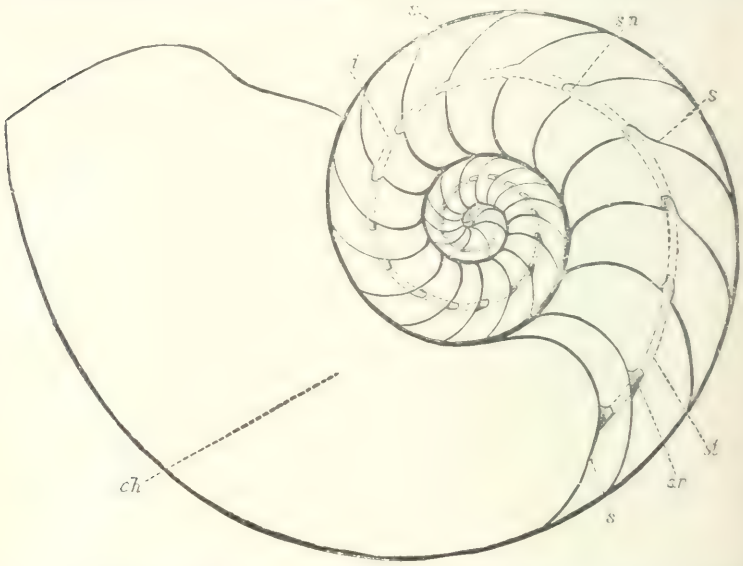



FIG. 263. *Nautilus pompilius*. Shell in section. *ch*, body chamber occupied by living animal; *s*, septum; *st*, siphuncle; *s.n*, septal neck. (From the Cambridge Natural History.)

has a pearly lining, is a spiral, symmetrically coiled in one plane, and consists of a series of chambers separated from one another by calcareous partitions or septa. As the shell is made larger and the animal grows, it moves forward, leaving a gas-filled chamber behind it, and then secretes the partition over the deeper surface of its body. In this way all the chambers have been formed. In the center of each partition is an opening through which a cylindrical stalk passes from the end of the animal's body to the extreme inner end of the spiral, thus traversing all the chambers.

## SUBCLASS II. DIBRANCHIATA

The Dibranchiata (Gr. *δίς*, two, and *βράγχια*, gills) are Cephalopoda with only two gills. The portion of the foot surrounding the mouth is divided into eight or ten arms, which bear from one to four rows of suckers, and the funnel is a completely closed tube, open only at each end. The shell is usually internal, and when external is never chambered. The members of this group are provided with an ink sac. The more striking or interesting individuals may best be considered under the two orders into which this subclass is generally divided, the classification depending on the number of arms surrounding the mouth.

### Order 1. Decapoda

The Decapoda (Gr. *δέκα*, ten, and *πούς*, foot) have eight sucker-bearing arms of nearly equal length, and two, much longer, tentacle-like arms, with suckers only near the tip; the suckers are cup-shaped and borne on little stalks. The body of the animal is generally elongated, often to a very considerable extent, and is provided with a pair of lateral outgrowths or fins. A shell is always present in the Decapoda; in one genus, Spirula (Fig. 264), it is spirally coiled but loosely, and is partially covered by the mantle; in all other genera it is flattened, consisting of a single plate or lamella and is internal — entirely inclosed by the mantle. In the genus Sepia, the cuttlefish (Fig. 260), this shell is calcareous and constitutes the cuttlebone. The cuttlefishes live near the shore and feed on Crustacea, Mollusca, and fishes; they are caught extensively and in some countries are eaten.

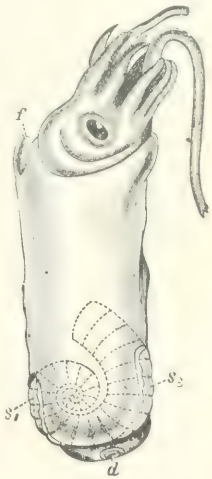



FIG. 264. *Spirula peronii*, lateral aspect. *d*, terminal sucker; *f*, fungiform [illegible] projecting portions of shell, the internal portion being shown in dotted lines. (From Parker and Haswell's Manual.)

In the genus Loligo (Fig. 265), to which the common squids belong, the shell is entirely chitinous; it is commonly called the pen of the squid because of its shape. In this country squids are used very extensively for bait, particularly in the cod fish-

eries; in Europe they are a common article of food in the seashore towns where are they abundant. They feed on small fishes and in turn are eaten by larger fishes. A number of giant squids, belonging to a different genus, have been thrown up on various coasts from time to time. They apparently live in deep water and only occasionally get stranded by storms. Some have been thrown up in various parts of the Pacific, some on the coasts of Ireland and Sweden, but the largest of all have been obtained in Newfoundland and Labrador. One of these had a body over six meters long, and one of its arms measured over ten and a half meters, making a total length of over sixteen and a half meters. Another measured about a meter less. In structure these squids are very much like the smaller species, but nothing is known of their habits.

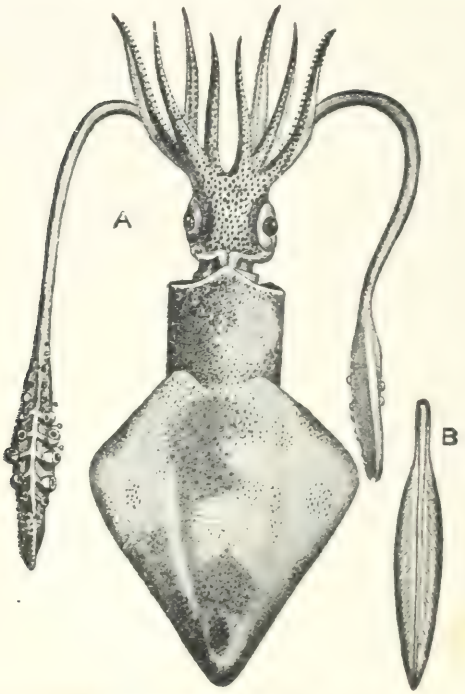



FIG. 2[illegible]. [illegible] squid. A, dorsal aspect; B, horny internal shell or pen. (From Parker and Haswell's Manual.)

### Order 2. Octopoda

The Octopoda (Gr. ὀκτώ, eight, and πούς, foot) have only eight arms surrounding the mouth, the two long, tentacle-like arms of the Decapoda being wanting. The suckers are not borne on stalks, but are sessile. The body is more rounded and relatively shorter than in the preceding order, and usually without lateral fins. There is no shell present, homologous with the shell of the Decapoda, but the female of one species, *Argonauta*

*argo*, the paper nautilus (Figs. 266 and 267), has membranes attached to two of the arms, and with these, as well as the nau-

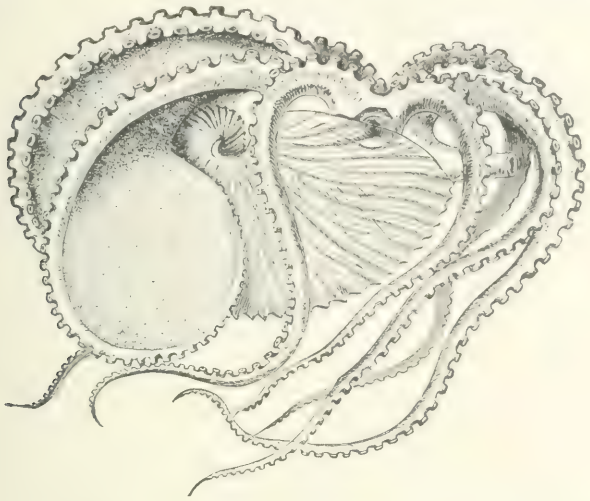


FIG. 266. *Argonauto argo*, the paper nautilus; female in shell. (After Claus.)

tle, secretes a delicate, slightly coiled shell, within which she sits; it is not fastened to the body of the animal and serves chiefly as a sort of nest for the eggs. The male is much smaller than the female, and, like the other Octopoda, is without a shell. The octopus, or devil-fish (Fig. 268), belonging to the genus Octopus, is represented by several species. They are probably not as bad as they are painted, and in the countries about the Mediterranean are largely used for food. Some species attain a great size, like the *Octopus vulgaris*

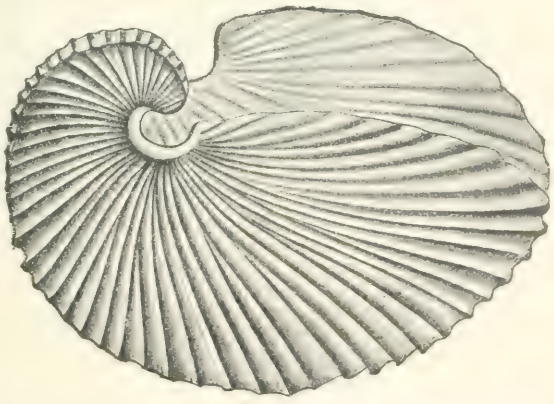


FIG. 267. *Argonauto argo*, the paper nautilus; shell. (After Parker and Haswell.)

of the Mediterranean and West Indies, which may become nearly three meters long and weigh thirty-four kilos, and the *Octopus punctatus* of the Pacific coast of the United States, which grows to a length of five meters.

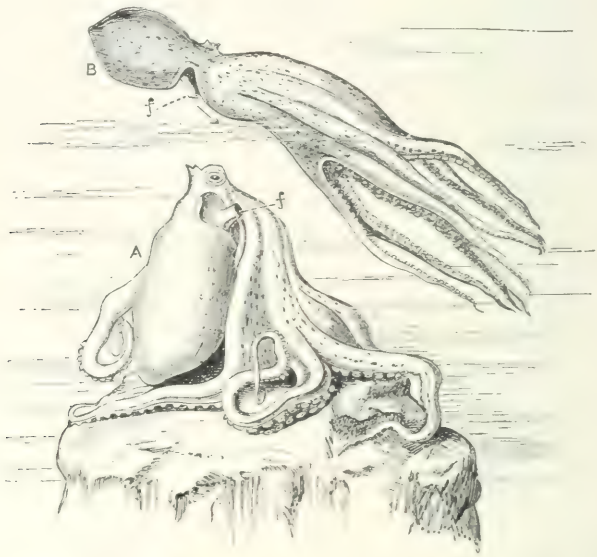



FIG. 268. *Octopus vulgaris*. A, at rest; B, swimming. *f*, funnel. (After Merculiano, from Parker and Haswell's Text-book.)

# CHAPTER IX

## TYPE VII. CHORDATA

The type Chordata (Lat. *chordatus*, having a cord) includes all the remaining animals, and is necessarily a very large type, although pretty sharply marked off from the others. For the Chordata all possess three characteristics in common which are found in no other type. First, the anterior portion of the alimentary canal is in communication with the outside by a series of slitlike openings in its walls; these are called gill slits, or gill clefts, and occur at some stage in the life history of all of the Chordata. Second, there is developed as an outgrowth from the dorsal wall of the alimentary canal a rod of tissue which is the foundation of the central or axial portion of the skeletal system of the body; this rod is called the *chorda dorsalis* or the notochord; it likewise appears at some stage in the development of the animal and may disappear before adult life. Third, the central nervous system lies exclusively on the dorsal side of the alimentary canal. There are other characteristics which apply to the type as a whole, but they can be discussed more intelligently under the various subtypes into which it is necessary to divide the Chordata. There are four such subtypes.

## SUBTYPE I. ENTEROPNEUSTA

The Enteropneusta (Gr. ἔντερον, intestine, and πνευστός, breathing) are represented by the genus Balanoglossus. Somewhat recently two deep-sea animals, Rhabdopleura (Fig. 260) and Cephalodiscus (Figs. 270 and 271), have been associated with it; but as their position is still somewhat doubtful and they do not appear to be of great systematic importance, they

need not concern us here to any extent. Rhabdopleura exists in the form of colonies; it has a so-called notochord but no gill slits. Cephalodiscus likewise occurs in colonies, but the individuals although inclosed in a common gelatinous investment

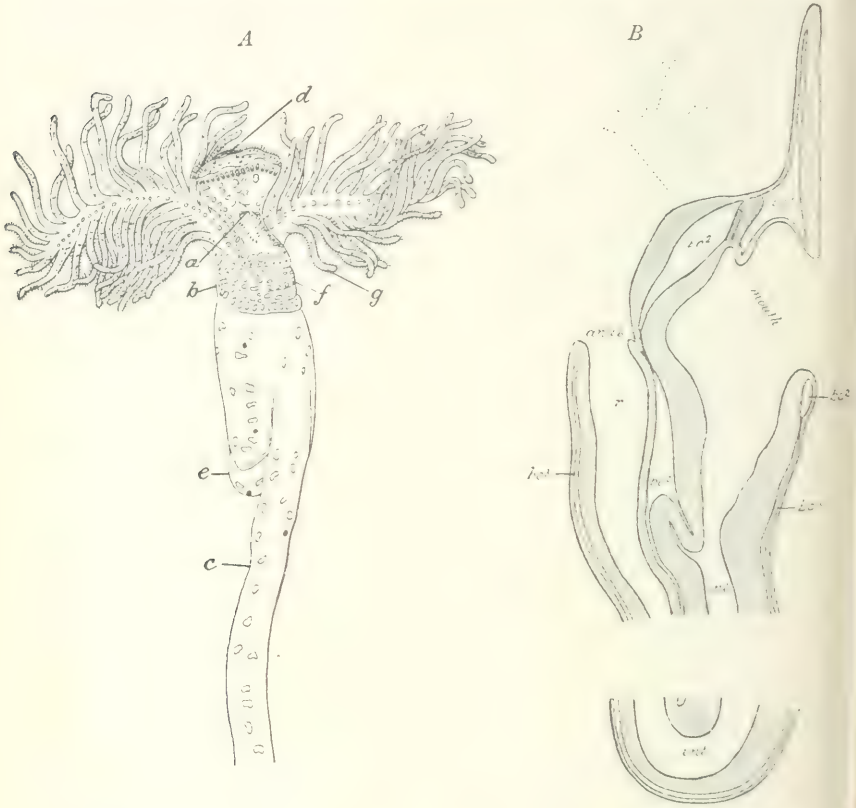



FIG. 269. *Rhabdopleura*. A, entire zoöid. *a*, mouth; *b*, anus; *c*, stalk of zoöid; *d*, proboscis; *e*, intestine; *f*, anterior region of trunk; *g*, one of the tentacles. (After [illegible]). B, diagrammatic longitudinal section a little to one side of the median line. [illegible] of proboscis; *cœ*², cœlom of collar; between *cœ*¹ and *cœ*² is a diverticulum; *cœ*³, cœlom of trunk; *int*, intestine; *r*, rectum. (After Fowler. Both A and B from Parker and Haswell's Text-book.)

are not organically connected with one another; there is a structure corresponding to a notochord, and a single pair of gill slits. Both of these animals are provided with tentacles, and as in Balanoglossus the body exhibits three regions, a proboscis, a collar, and a trunk.

Balanoglossus (Fig. 272) is a marine animal, living in the sand along the shore, and has a soft, wormlike body, ordinarily from ten to fifteen centimeters long. It is nearly cylindrical and exhibits three regions, an anterior proboscis, a short collar, and the elongated trunk. At the point where the proboscis joins the collar is the mouth on the ventral side, and on the dorsal side, a pore connecting with a part of the body-cavity. Just posterior to the collar is a series of slits on each side of the

FIG. 270. *Cephalodiscus*, gelatinous investment. (After McIntosh, from Parker and Haswell's Text-book.)

trunk on the dorsal surface; these are the gill slits and connect with the anterior portion of the alimentary canal. The gill slits increase in number during the life of the individual, new openings forming at the posterior end of the series. In some species there is a ridge on each side of the anterior portion of the trunk, the genital ridge, caused by the gonads or germ-glands situated within. The rings which appear on the posterior portion of the trunk are purely superficial. The glands of the skin secrete a viscid substance which serves to cement

together particles of sand, thus forming a sort of tube for the animal.

The digestive tract is a relatively simple, straight tube,

FIG. 271. *Cephalodiscus*. A single individual, enlarged. (After McIntosh, from Parker and Haswell's Text-book.)

terminating in the anus at the posterior tip of the body. Of the other internal organs we need merely note that there is a structure believed to be homologous with the notochord, which

lies in the region of the collar and proboscis; that the nervous system is widely distributed over the body, the most highly differentiated portion lying on the dorsal side of the collar, and that there is a well-developed blood system and body-cavity. The sexes are separate. In some species the development is direct, in others a larva is produced, called Tornaria

FIG. 272. *Balanoglossus*. Dorsal aspect. *br*, branchial region; *co*, collar; *gen*, genital ridges; *hep*, elevations formed by hepatic cæca; *pr*, proboscis. (After Spengel, from Parker and Haswell's Manual.)

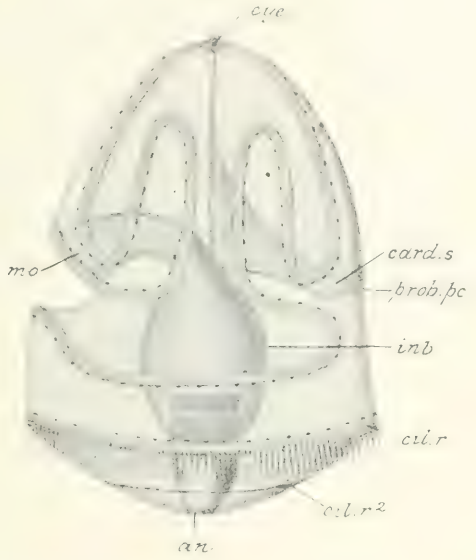



FIG. 273. *Tornaria*, the larva of *Balanoglossus*. Lateral aspect; magnified. *an*, anus; *card.s*, cardiac sac; *cil.r*, post-oral ciliated band; *cil.r*$^2$, posterior ciliated ring; *eye*, eye-spot on apical plate; *int*, intestine; *mo*, mouth; *prob.po*, proboscis pore. (After Spengel, from Parker and Haswell's Text-book.)

(Fig. 273), which is much like the larvæ of the Echinodermata.

The systematic position of Balanoglossus is still in dispute: by some it is classified with the worms; by many it is believed to be closely related to the Echinodermata because of its larva; by the majority it is placed with the Chordata.

## SUBTYPE II. TUNICATA

The Tunicata (Lat. *tunica*, mantle), sometimes called the Urochorda (Gr. οὐρά, tail, and χορδή, cord), are all marine animals of wide distribution. They vary from a few millimeters to ten or fifteen centimeters in length, and a few are brilliantly colored. Some are attached throughout their adult life and are known popularly as sea squirts or scientifically as ascidians (Gr. ἀσκίδιον, bag); others are free-swimming and for the most part pelagic, *i.e.* near the surface of the ocean; they are generally very transparent like the jellyfishes. In both the attached and the free-swimming Tunicata some genera consist of simple individuals, each living singly by itself, while others are compound, several or many individuals being associated in a colony.

FIG. 274. *Ascidia*. External view from right side; the branchial opening at the tip, the atrial on the side. (After Herdman, from Parker and Haswell's Manual.)

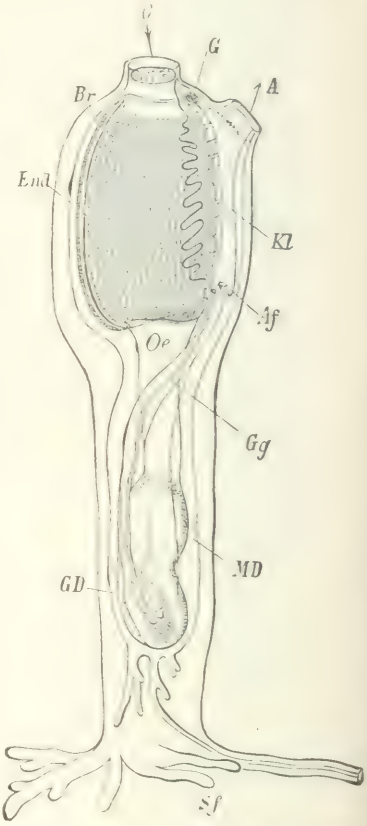



FIG. 275. *Clavellina lepadiformis*, somewhat diagrammatic. *A*, atrial or exhalant pore; *Af*, anus; *Br*, gills; *End*, endostyle; *G*, brain; *GD*, germ-gland; *Gg*, genital duct; *Kl*, atrium; *MD*, stomach; *O*, mouth; *Oe*, œsophagus; *Sf*, stolons. (From Claus and Sedgwick's Text-book.)

The group derives its name from the outer covering of the body, which consists of a test or tunic, largely a secreted structure composed of a substance resembling vegetable cellulose, but containing some stellate cells and a few blood vessels. It

varies greatly in appearance in different groups, being sometimes gelatinous, sometimes leathery, either transparent or opaque, and with a smooth or warty surface. A typical sea squirt appears externally as a saclike body, attached at one end, with an opening at the opposite end and a second opening at a greater or less distance from the first on the side of the body (Fig. 274). The first of these openings is called the branchial aperture, the second is the atrial aperture. Around these apertures there are frequently pigment spots, which are probably sensory and may represent organs of sight.

The tunic is lined by a portion of the body wall of the animal called the mantle, which is provided with strong muscle bands.

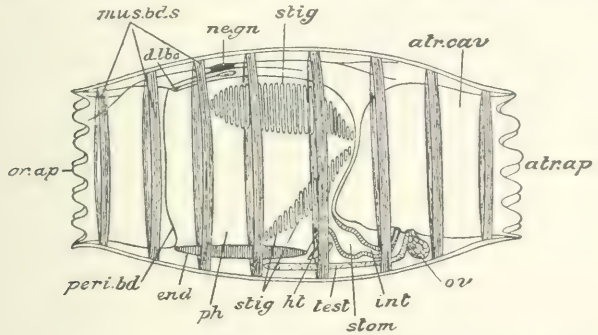



FIG. 276. *Doliolum*. Diagram of the sexual form. *atr.ap*, atrial pore; *atr.cav*, atrial cavity; *d.lbc*, dorsal tubercle; *end*, endostyle; *ht*, heart; *int*, intestine; *mus.bds*, muscle bands; *ne.gn*, nerve ganglion; *or.ap*, oral aperture; *ov*, ovary; *peri.bd*, peripharyngeal band; *ph*, pharynx; *stig*, stigma; *stom*, stomach; *test*, testis. (After Herdman, from Parker and Haswell's Text-book.)

The cavity within the mantle is called the atrium; it corresponds to a portion of the outside world with which it is in direct communication through the atrial aperture. In the atrium the body is freely suspended, being attached only along the ventral side. The branchial aperture or mouth opens into a large chamber, the branchial chamber or anterior portion of the alimentary canal, whose walls are pierced by very numerous gill slits, which thus connect it with the atrium. The branchial chamber opens by means of a short œsophagus into the stomach, and this into the intestine, which terminates on the dorsal side of the branchial chamber by means of an anus opening into the atrium. There is a heart, which possesses the

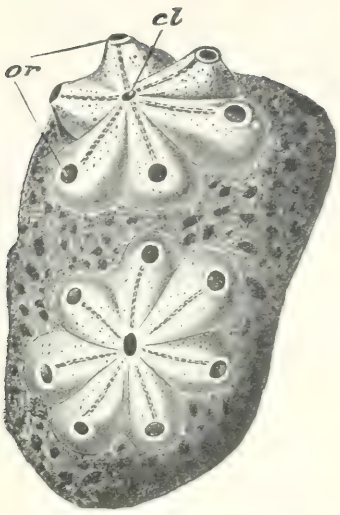



FIG. 277. *Botryllus violaceus*. Two colonies. *cl*, common cloacal or atrial opening; *or*, oral or branchial openings. (After Milne-Edwards, from Parker and Haswell's Manual.)

peculiar power of sending the blood alternately in opposite directions. The nervous system is a single dorsal ganglion with nerve fibers going to various parts of the body (Fig. 275). The Tunicata are hermaphroditic; the ovary and testes lie near each other, and their ducts open on the dorsal side of the body into the atrium near the anus. Cross fertilization generally takes place, however, since the ova and spermatozoa do not mature simultaneously in the same individual.

The structure of the free-swimming Tunicata (Fig. 276) is essentially like that of the ascidian just described, but the tunic is very thin, and the branchial and the atrial apertures are at opposite ends of the body, which is usually more or less barrel-shaped, with the muscle bands of the mantle arranged circularly like hoops. In the compound Tunicata the individuals are all inclosed in a common continuous tunic; there is a branchial aperture for each individual, while sometimes there is a single atrial aperture for the whole colony, as in Botryllus (Fig. 277), and sometimes each individual has an atrial pore which opens into a large

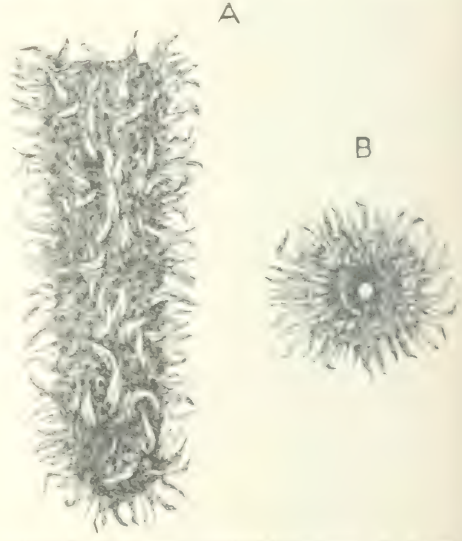



FIG. 278. *Pyrosoma*, a colonial tunicate. A, lateral aspect; B, end view. (After Herdman, from Parker and Haswell's Text-book.)

common chamber with one external opening, as in Pyrosoma (Fig. 278).

The fertilized egg of the Tunicata generally develops into a larva called the tadpole larva because, although very small, it resembles in shape the tadpoles, which are the larval stage in the development of the frogs and toads. This tadpole larva is very interesting because it possesses in its tail region a well developed notochord. In one group which retains in its adult condition the general form of the larva, this notochord persists; but in all other Tunicata it disappears in the course of develop-

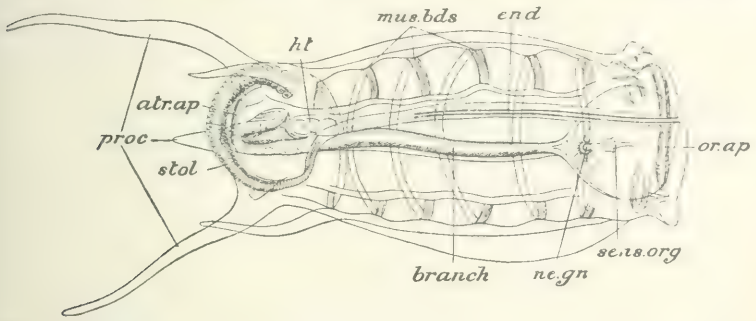



FIG. 279. *Salpa democratica*, asexual form, ventral aspect. *atr.ap*, atrial aperture; *branch*, dorsal lamina; *end*, endostyle; *ht*, heart; *mus.bds*, muscle bands; *ne.gn*, nerve ganglion; *proc*, processes at the posterior end; *sens.org*, sensory organ; *stol*, stolon. (After Vogt and Jung, from Parker and Haswell's Text-book.)

ment and so is absent in the adult. Some of the free-swimming genera have a rather complicated development since there is an alternation of generations. The fertilized ovum develops into a non-sexual individual which possesses a process on the body wall called the stolon; from this stolon sexual individuals may be produced by budding (Fig. 279). This alternation of generations is very conspicuous in such genera as Salpa and Doliolum.

## SUBTYPE III. CEPHALOCHORDA

The subtype Cephalochorda (Gr. κεφαλή, head, and χορδή, cord), variously known as Leptocardii (Gr. λεπτός, slender, and καρδία, heart) and Acrania (Gr. ἀ, without, and Lat. *cranium*, skull), is represented by a single genus, Amphioxus, the lancelet, which by some zoölogists is classified under the next subtype.

*Amphioxus lanceolatus* (Fig. 280) is a more or less fishlike little animal, about five centimeters long, exclusively marine, which lives buried vertically in the sand in relatively shallow water on tropical and temperate shores. In Europe it has been found in the Mediterranean, the English Channel, and the North Sea, and in North America along the southern portion of the eastern coast of the United States and at Bermuda; it also lives on many shores in the Pacific Ocean.

The body is somewhat compressed laterally and pointed at both ends. At the anterior end on the ventral side is the mouth, surrounded by a circle of bristlelike processes called

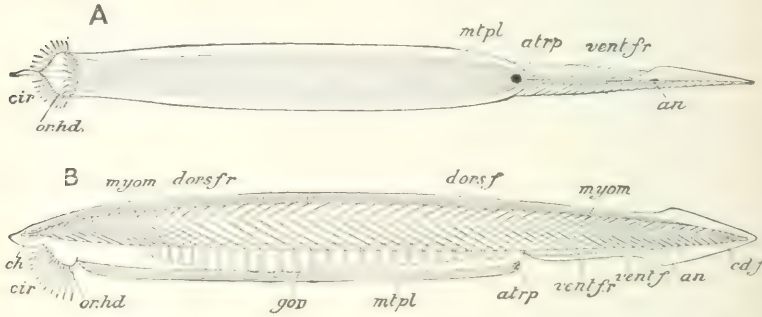
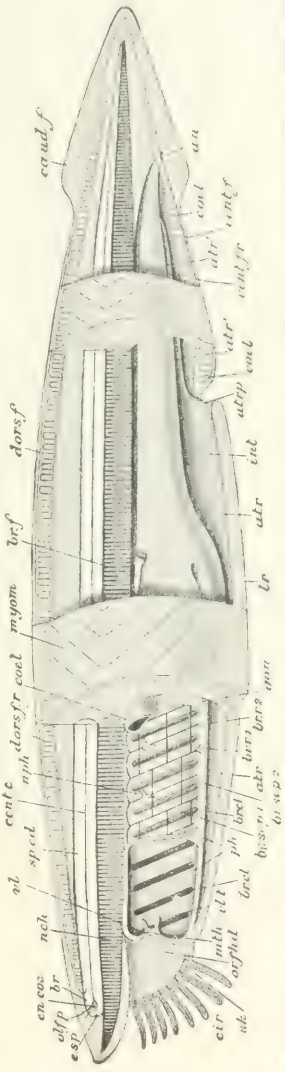



FIG. 280. *Amphioxus lanceolatus*. A, ventral aspect; B, side view. *an*, anus; *atrp*, atrial pore; *cd.f*, caudal fin; *cir*, cirri; *dors.f*, dorsal fin; *dors.f.r*, dorsal fin-rays; *gon*, gonads; *mtpl*, metapleure; *myom*, myomeres; *nch*, notochord; *or.hd*, oral hood; *vent.f*, ventral fin; *vent.f.r*, ventral fin-rays. (After Kirkaldy, from Parker and Haswell's Manual.)

cirri. Along the dorsal side of the body for its entire length is a slight elevation, the dorsal fin, which is directly continuous with a somewhat greater caudal or tail fin about the posterior end of the body. On the ventral side of the body there is no unpaired fin on the anterior two thirds, but instead two longitudinal folds placed somewhat laterally; at the posterior end of these folds is an opening on the median line, called the atrial pore, and from this an unpaired median ventral fin runs backward to become continuous with the caudal fin. Some distance posterior to the atrial pore is the anus, placed slightly to the left of the median ventral line.

Internally (Fig. 281) there is a well-developed *chorda dorsalis* extending the entire length of the body, and dorsal to this is the rodlike central nervous system, the neural tube, the anterior

end of which is modified into a simple brain. On the anterior surface of the brain is an unpaired pigment spot, the organ of sight. Ventral to the notochord is the alimentary canal, of which the anterior portion forms a long pharynx with very numerous gill slits in its walls. There are two rows of these slits, a row on each side of the body, and instead of opening directly to the outside, they open into a chamber, the atrium, which communicates with the outside through the atrial pore already mentioned. Posterior to the pharynx is the intestine, from the anterior end of which a diverticulum arises, directed forward and to the right, called the liver. Excretory organs occur in the region of the gill slits, and the germ-glands, or gonads, lie in two longitudinal series, a right and a left, on the inner walls of the atrial chamber, into which the germ-cells pass when mature, and so out through the atrial pore. The sexes are separate.




The muscles are very well developed on each side of the body. They are divided up into segments, or myomeres, which are shaped like hollow wedges fitting into one another, with the point of the wedge directed forward. There

is a corresponding segmental arrangement of nerve fibers given off from the spinal cord. The segments on the two sides of the body are not opposite one another, but alternate in position. The tendency at the present day is to regard Amphioxus as closely related to the following subtype, and as we have already noted, some zoölogists place it within that group.

## SUBTYPE IV. VERTEBRATA

The Vertebrata (Lat. *vertebratus*, jointed) comprise what are commonly called the higher animals in distinction from those which we have considered up to this point, which are often called the Invertebrata (Lat. *in*, without, or not, and *vertebratus*, jointed). In addition to the general characteristics which the Vertebrata possess in common with the other Chordata, they always have some kind of an axial skeleton developed about the notochord. This skeleton consists of segmentally arranged parts, the vertebræ, and comprises a cranium, which incloses the brain, and the vertebral column or backbone, which generally incloses the neural tube. In the course of the development of the vertebral column the notochord may persist, or it may be partially or wholly obliterated. The central nervous system always has the form of a tube, which is modified at its anterior end to form a brain.

The paired lateral appendages of the Vertebrata never exceed two pairs, and two pairs are present in most cases; the more anterior pair is known as the pectoral, the more posterior as the pelvic. These appendages are likewise provided with a skeleton, called the appendicular skeleton. The blood consists of a nearly colorless fluid in which there are colorless cells, the white blood corpuscles, and also colored cells, commonly called the red blood corpuscles; to these latter the color of the blood is due. Reproduction in the Vertebrata is always sexual. This group is divided into six classes, the members of which are known commonly as fishes, amphibians, reptiles, birds, and mammals.

### CLASS I. CYCLOSTOMATA

The Cyclostomata (Gr. *κύκλος*, circle, and *στόμα*, mouth) consist of the lamprey eels and the hag-fishes or slime eels. While

they are popularly classed as fishes, they differ so strikingly from the true fishes that zoologists place them in a class by themselves. Lampreys (Fig. 282) are found in both fresh and salt water, and the salt-water species ascend the rivers to spawn; the hag-fishes are marine. They all have elongated bodies covered with a smooth, slimy skin. The paired appendages which are present in most Vertebrata are entirely wanting. There may be one or two dorsal fins and a caudal fin more or less well de-

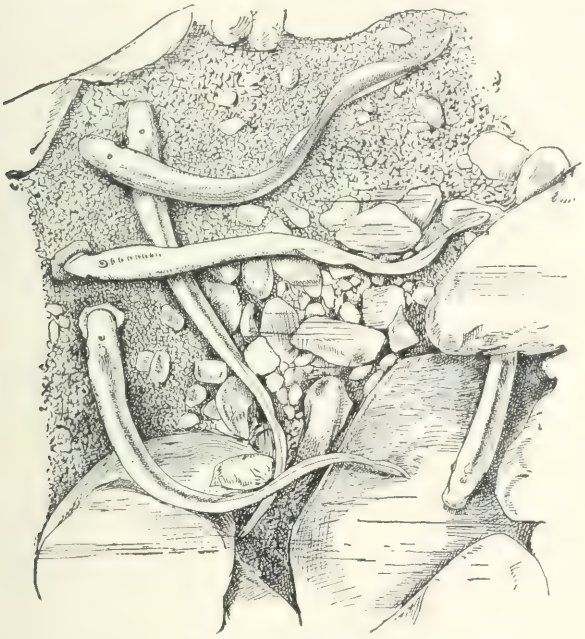


FIG. 282. *Petromyzon wilderi*, the musk lamprey, in the act of spawning. (From Shipley and MacBride's Zoölogy.)

veloped. The largest lamprey is a marine species, *Petromyzon marinus*, which attains a length of a meter; the fresh-water species vary from about fifteen to sixty centimeters. At the anterior end of the body on the ventral side is a large, funnel-shaped depression, whose walls are covered with conical chitinous projections or teeth (Fig. 283). At the deep end of the funnel is the circular mouth, without jaws, through which the muscular tongue, provided with rasplike teeth, may be protruded. There is a pair of well-developed eyes, and on the dorsal side of

the head a single opening on the median line, the nasal aperture. Along each side of the body, posterior to the eyes, is a row of seven gill slits.

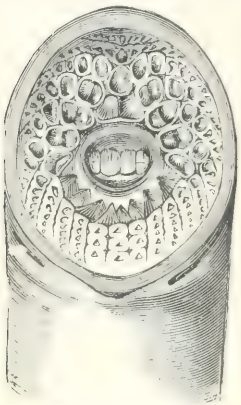


FIG. 273. *Petromyzon marinus*, lamprey eel. Head seen from below, showing horny teeth of buccal cavity. (From Claus and Sedgwick's Textbook.)

There is a well-developed notochord, and in the region of the neural tube are segmentally arranged cartilages, which correspond to vertebræ. The rest of the skeleton consists of a cartilaginous brain case or cranium, numerous cartilages in the head and funnel, and a complicated series supporting the gills and called the branchial basket. There is a good-sized mouth cavity, which communicates posteriorly with two tubes, a ventral, the respiratory tube, which is closed posteriorly and whose walls are pierced by the gill slits, and a dorsal, the œsophagus, which opens into a slight enlargement, the stomach (Fig. 284). Connected with the stomach is a single-lobed liver. The intestine is a relatively straight tube with a posterior enlargement, the rectum terminating in the anus. The heart lies just posterior to the gills. The large body-cavity contains, in addition to the alimentary canal and the liver, the kidneys, a pair of band-shaped, elongated structures, and the single, very large germ-gland. The ova or spermatozoa are discharged into the body-cavity and pass to the outside through two pores near the anus; these are called the abdominal pores. The muscles of the body are arranged in myomeres. In the course of development a larva is formed, called Ammocœtes; its eyes are very rudimentary and concealed beneath the skin.

The lamprey feeds on various small aquatic animals and sometimes attaches itself by its suckerlike funnel to the bodies of fishes, and then scrapes away the flesh by means of its tongue. Lampreys were considered a great table delicacy by the Romans, and they are still largely eaten in parts of Europe and in some parts of America. The Germans call them "nine-eyes."

The hag-fishes or slime eels differ from the lampreys chiefly in the almost entire absence of dorsal fins and in the presence

of short tentacles about the funnel; there are also several differences of internal structure. The skin of these animals is

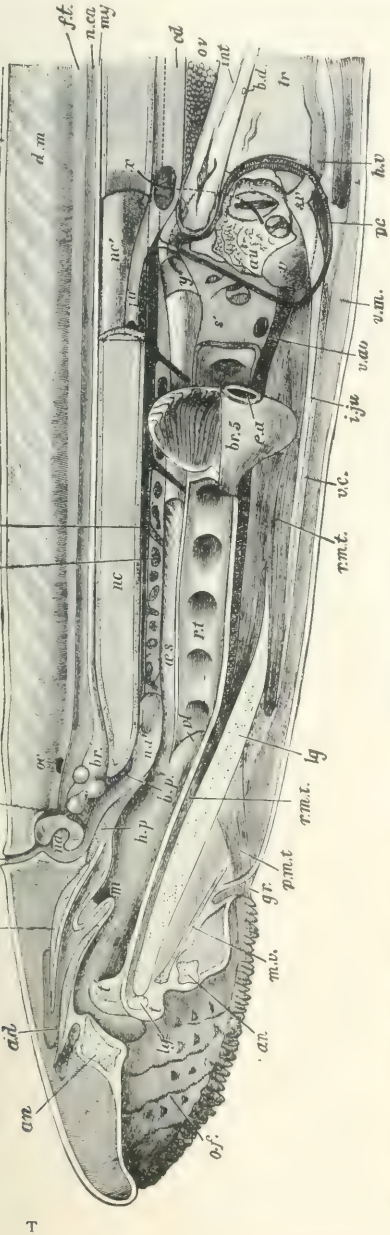



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FIG. 284. *Petromyzon marinus*. Dissection of the anterior portion of a female; the cartilages and notochordal sheath are dotted. *a.d.*, anterior dorsal cartilages; *am.*, annular cartilage; *an.*, auricle, cut open; *b.d.*, aperture of bile-duct (abnormal); *b.p.*, portion of basal plate; *br.*, brain; *br.s.*, fifth left gill-sac, the upper half cut open; *cd.*, left cardinal vein; *d.ao.*, dorsal aorta; *dm.*, dorsal muscles; *ed.*, external aperture of fifth gill-sac; *f.f.*, fibrous tissue of buccal canal; *g.r.*, groove; *h.p.*, portion of basal plate; *h.v.*, integument; *i.ju.*, inferior jugular vein; *int.*, intestine; *ju.*, jugular vein; *l.*, lingual cartilage; *l.c.*, small cartilage attached to lingual; *liv.*, liver; *m.*, buccal cavity; *ms.*, median ventral cartilage; *my.*, spinal cord; *na.*, olfactory sac; *ne.*, pituitary pouch; *na'.*, nasal aperture; *na.c.*, nasal capsule; *n.*, *n.*, notochord; *n.ca.*, spinal canal; *o.*, cranial roof; *o.*, œsophagus; *o.f.*, buccal funnel; *ov.*, ovary; *p.*, pericardium; *p.d.*, posterior dorsal cartilage; *p.m.d.*, protractor muscle of tongue; *p.m.t.*, retractor muscle of tongue; *r.m.t.*, its tendon; *r.r.*, respiratory tube; *s.*, lymph sinus surrounding œsophagus; *s.a.*, sinus venosus; *t.*, tongue; *v.*, ventricle; *v.ao.*, ventral aorta; *v.c.*, ventral cartilage of branchial basket; *v.c.*, vena cava; *v.m.*, mesenteric vein; *x*, lymphatic sinus in roof and wall of buccal cavity; *y*, lymphatic sinus in wall of buccal cavity; *z*, lymphatic sinus venosus into auricle; *y*, bristle passing from œsophagus into mesentery. (From Parker's Zoötomy.)

capable of secreting enormous quantities of mucus or slime. In one genus the gill slits open directly to the outside, as in the lampreys; in another, Myxine, they open into a pair of longitudinal ducts each of which opens to the outside by a single pore. This Myxine, which is about forty-five centimeters long, while living ordinarily buried vertically in the sand, may bore its way into fishes, particularly the cod, and feed on its flesh, thus being a temporary parasite and the only example of this condition found in the Vertebrata. Myxine is said to be hermaphroditic, but recent investigations make this appear doubtful; the spermatozoa are supposed to mature first and the ova later.

## CLASS II. PISCES

The Pisces (Lat. *piscis*, fish) include all the fishes except the Cyclostomata. They are commonly called cold-blooded animals, since the temperature of the body is much the same as that of the surrounding medium. They are all aquatic, and consequently gills are always present as organs of respiration. The general shape of the body varies greatly; there is no movable neck such as is present in many higher Vertebrata, but the head joins the trunk of the body, and the trunk passes gradually into the tail region without any abrupt reduction in size (Fig. 285). In the anterior portion of the body the vertebræ are capable of very little motion on one another; but in the tail they are very movable, and so this becomes the principal organ of locomotion.

The head bears a pair of well-developed eyes and nostrils, but there are no auditory openings, although internal ears are present; these are believed to serve the function of orienting the body rather than of hearing. The mouth may be ventral or at the anterior end of the head, and is usually provided with teeth. Most fish have the body covered with scales, and there are always unpaired fins along the median line; these fins vary greatly in number, but generally consist of one or more dorsal fins, a caudal fin, and one or more ventral or anal fins posterior to the anus on the ventral side of the body; they are supported by skeletal structures called fin-rays.

The tail presents several types. The vertebral column may be straight at its posterior end and surrounded by a symmetrical

tail fin; such a tail is called diphycercal (Figs. 305 and 307). Or, more commonly, the posterior end of the vertebral column may be bent upwards, toward the dorsal side, forming a heterocercal tail (Fig. 285); in this case the outline of the caudal fin may be asymmetrical, as in sharks, or it may be symmetrical despite the shape of the vertebral column, and is then sometimes called a homocercal tail (Figs. 297 and 298). In addition to the unpaired fins there are generally two pairs of paired fins, an anterior pair, the pectoral, and a posterior pair, the pelvic; sometimes the pelvic fins lie very far forward, even anterior to the pectoral, but in such cases the pectoral fins are the more dorsal in position. Running longitudinally along each side of the body is a more or less distinct line; this is called the lateral line, and marks the position of a series of sense organs, which also extend over the head.

The gills are delicate processes or folds, rich in blood vessels, attached to the walls of the gill clefts. They are supported by skeletal structures, the gill or branchial arches. In some fishes the number of gill clefts visible on the exterior of the body is the same as in the wall of the pharynx, but in most fishes there is a fold of the skin which covers the gills, leaving only a single external opening on each side of the body. This fold is called the operculum (Fig. 297) and is supported by skeletal structures. While the fishes are sharply marked off from the other

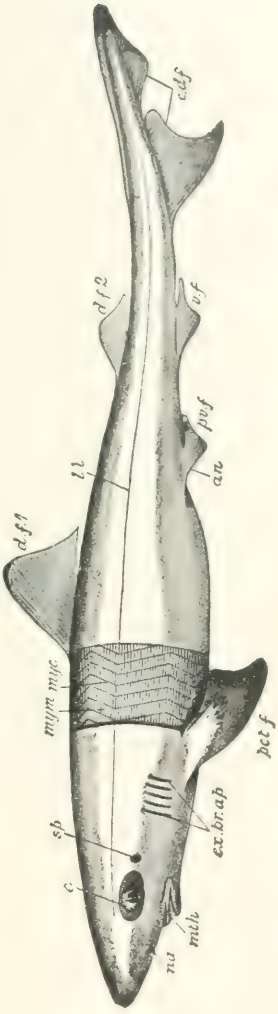


FIG. 285. *Mustelus antarcticus*, a dogfish. Lateral aspect with a portion of the skin removed. *an*, anus; *c.d.f.*, caudal fin; *d.f.1*, *d.f.2*, dorsal fins; *e*, eye; *ex.br.ap*, external branchial aperture; *l.l.*, lateral line; *mth*, mouth; *myc*, myocommata; *mym*, myomeres; *n.a*, nasal aperture; *pct.f.*, pectoral fin; *pv.f.*, pelvic fin; *sp*, spiracle; *v.f.* ventral fin. (From Parker's Biology.)

Vertebrata, there is still considerable difference of opinion concerning the subdivision of the class itself; we may divide it into three subclasses.

## SUBCLASS I. ELASMOBRANCHII

The Elasmobranchii (Gr. ἐλασμός, a metal plate, and βράγχια, gills) are sometimes called the Selachii (Gr. σέλαχος, shark), although this name is perhaps better reserved for the principal order under the subclass. There are two or three extinct orders; all the living representations of the group are classified under two orders, the one represented by the sharks and the skates and the other by the Chimæra or sea cat. They are almost all marine fishes, and the skin is usually provided with scales, sometimes very numerous; each scale consists of a bony plate embedded in the skin; attached to this plate is a sharp spine with its tip pointed backward. The spine is of a very hard bony substance called dentine, and is covered with a thin layer of a still harder substance, the enamel. These scales are called placoid scales, and resemble vertebrate teeth in their ultimate structure. Sometimes they are few in number and large, as in some skates; again, they are very small and arranged close together as in dogfishes; in the latter case the skin of the fish is known as shagreen, and is used in polishing various objects.

Typically the Elasmobranchii have two dorsal fins, each provided with a sharp, horny spine, a heterocercal caudal fin, one anal fin, and well-developed pelvic and pectoral fins (Fig. 285). A caudal fin is sometimes absent. The pelvic fins are placed pretty far back near the anal opening, and in the male are always provided with hooks or claspers, which serve as copulatory organs. The ova, which are very large, are almost always fertilized within the body of the female, and in some cases the young are born well-developed, so that such species are viviparous.

Of the internal anatomy we need note merely that the skeleton is never of bone, but always of cartilage, which, however, is often calcified, in places at least. The notochord is more or less completely replaced by cartilaginous vertebræ, often calcified, and the brain is inclosed in a solid cartilaginous box or cranium without sutures or joints. The intestine is of impor-

tance because it is always provided within with a spiral membrane or fold, extending from the wall into the lumen of the

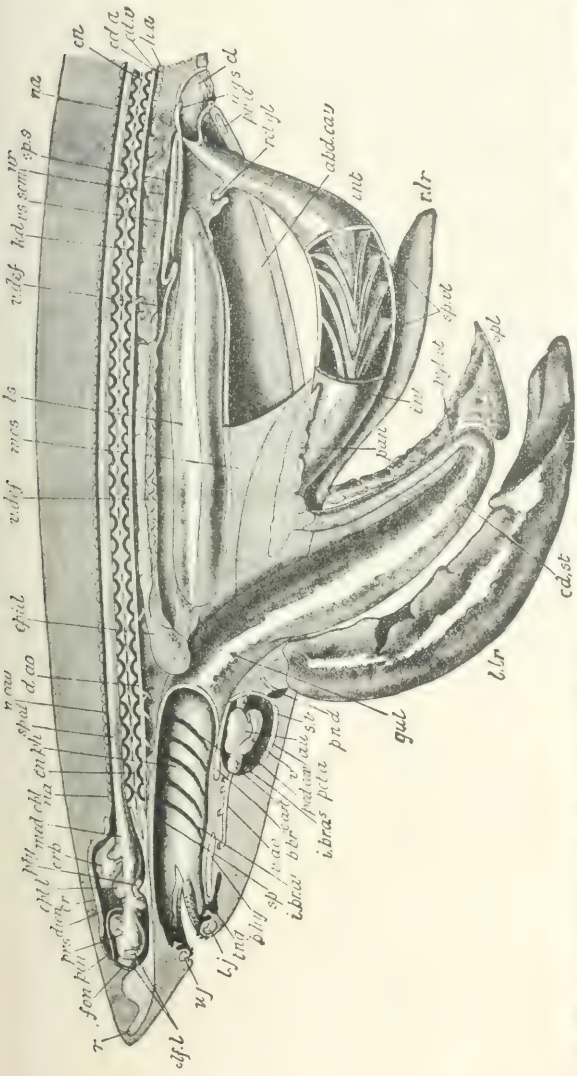

FIG. 286. *Scyllium canicula*. A dogfish, dissected, cartilages dotted, calcified ends of vertebræ black. *abd. ca. v*, abdominal cavity; *au*, auricle; *b. br*, basi-branchial cartilage; *cbr*, basi-hyal; *cart*, conus arteriosus; *d. ca*, caudal portion of stomach; *cd*, caudal vein; *ch*, chorda; *cr*, cranium; *cb*, cerebellum; *d. ca*, descending portion of stomach; *d. cav*, cardinal vein; *d. ep*, epididymis; *fon*, fontanelle in roof of skull; *ha*, hæmal arches; *h. d*, hæmal duct; *h. ep*, hæmal duct of epididymis; *k*, kidney; *l. dr*, left lobe of liver; *l. jm*, lower jaw; *l. lr*, left lobe of liver; *l. pa*, left pancreas; *l. pl*, left pleuro-peritoneal cavity; *l. v*, left ventricle; *lam. pancreas*; *p. abd. v*, post-abdominal vein; *p. ca*, post-caudal vein; *p. cav*, pericardial cavity; *p. d*, pancreatic duct; *pect*, pectoral fin; *pericard*, pericardium; *per. body*, pearl organ; *per. arch*, perivisceral arch; *r*, rostrum; *r. d*, renal duct; *r. p*, renal portal vein; *sem. d*, semicircular canal; *sp*, spleen; *sp. v*, spiral valve; *s. v*, sinus venosus; *teg. lodgic*, tegmen lodgicum; *tent*, tentacle; *v. d*, vas deferens; *v. ep*, vas efferens epididymis; *ven. d*, ventral aorta; *v. abd. v*, vas-deferens; *v. ren. v*, renal portal vein; *w*, uterus; *v*, ventricle; *vert*, ventral aorta; *v. abd. v*, vas-deferens; *v. ren. v*, renal portal vein; *w*, uterus; *v*, ventricle; *vert*, vertebral centrals. (After Parker and Haswell.)

tube, and serving to increase the absorbing surface (Fig. 286). This is called the spiral valve, and is particularly necessary on account of the short length of the intestine. The other impor-

tant characteristics of the group may best be considered under the two orders.

### Order 1. Selachii

The Selachii (Gr. σέλαχος, shark) include all the sharks and skates, or rays. The general shape of the body of the sharks is more or less spindlelike (Fig. 287). They have the typical fins already described well developed. The head bears the eyes, placed laterally or slightly dorsally, the two nostrils, which are ventral, and the mouth, which is a transverse slit on the ventral

FIG. 287. *Lamna cornubica*. A shark. (From Dean's Fishes.)

side of the head provided with upper and lower jaws, which bear numerous rows of teeth. The general shape of the head is sometimes curiously modified, as in the hammer-headed shark, which has two thick lateral processes bearing the eyes at their extremities, and as in the sawfish shark, which has the head greatly prolonged anteriorly, and provided with sharp, triangular teeth on each side like a saw.

Back of the head and just anterior to the pectoral fins are the external gill slits, never covered by an operculum; usually there are five pairs, lateral in position, but in some there are six and in some seven. Between the gill slits and the eye on each side of the body is an opening leading from the mouth cavity or pharynx to the outside; it is called the spiracle, and corresponds to a non-functional gill cleft. Posterior to the pelvic fins is a single opening on the median line, the cloacal opening, and near it a pair of smaller openings, the abdominal pores, which, like the corresponding structures in the Cyclostomata, open into the abdominal cavity. The cloacal opening leads into a chamber, the cloaca, into which open the rectum, the genital

ducts, and the urinary ducts from the kidneys. Dorsal to the rectum in the abdominal cavity is a peculiar gland, the rectal gland.

The fundamental structure of the skates or rays is the same as that of the sharks; the chief difference lies in the general

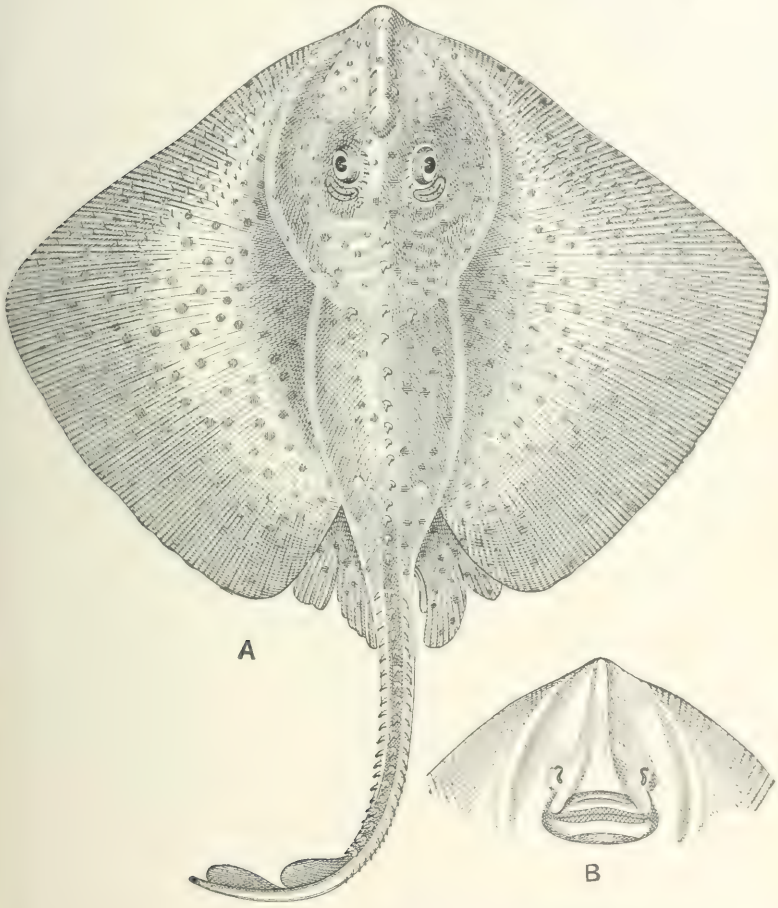


FIG. 288. *Raia maculata*, a skate. A, dorsal surface, showing spiracles just posterior to the eyes; B, ventral surface, anterior end, showing nasal pits and mouth. (From Sh[illegible] and MacBride's Zoölogy.)

shape of the body, which is due to the great flattening dorsoventrally, and the enormous development of the pectoral fins, which spread out laterally from the tip of the head to beyond the pelvic fins (Fig. 288). This brings the gill clefts to the

ventral side of the body, and the eyes and spiracles to the dorsal side. The dorsal and tail fins are usually but slightly developed. Many of the Selachii are viviparous, the young being developed in an enlargement of the oviduct, which is called the uterus. In most other cases the ova are surrounded by a firm, chitinous capsule, which is secreted by the walls of the oviduct; it usually has long, threadlike filaments which become entangled in seaweed or other objects, and so anchor the egg during its development (Fig. 289). The dried empty capsules are familiar objects on the seashore, and are known popularly as "mermaids' purses."

FIG. 289. Egg case of dogfish. (After Dean, from Parker and Haswell's Manual.)

In their general habits of life the sharks and rays differ widely. The sharks of all sorts and their allies, the dogfishes, are active, free-swimming animals, living near the surface, feeding on fishes and other relatively large animals, and possessed of great muscular strength. None are very small, and the largest attain a length of from eleven to more than twelve meters. The maximum length is reached by the basking shark, Cetorhinus, which is the largest living fish known. The rays are sluggish, living for the most part in shallow water on the bottom of the ocean; they feed chiefly on Crustacea and Mollusca, and sometimes attain a diameter of nearly five meters. Skates are eaten by man to some extent. One of the most curious rays belongs to the genus Torpedo, the electric ray. Several genera of the Selachii have the power of generating electricity in certain parts of the body, and giving a considerable electric shock; this power is best developed in Torpedo, in which the electric organ, consisting of modified muscles, lies on either side of the head and branchial region, and extends the entire thickness from the dorsal to the ventral side. By placing the fingers on the ventral side and the thumb on the dorsal, the shock is readily felt.

## Order 2. Holocephali

The Holocephali (Gr. ὅλος, whole, and κεφαλή, head) have long been placed in a subclass by themselves, owing to the structural differences between them and the Selachii. But some recent information concerning their development, taken together

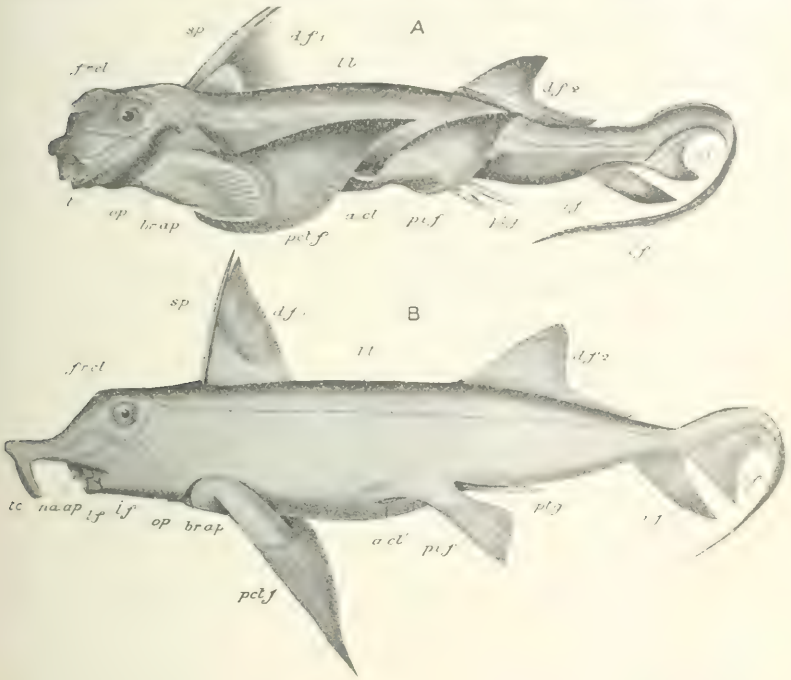


FIG. 290. A, *Chimæra monstrosa;* B, *Callorhynchus antarcticus*. *a.cl*, anterior clasper; *a.cl'*, pouch for its reception; *br.ap*, branchial aperture; *c.f*, caudal fin; *c.f'*, its whiplike prolongation; *d.f.1*, *d.f.2*, dorsal fins; *fr.cl*, frontal clasper; *l.f*, *l.f'*, labial folds; *l.l*, lateral line; *na.ap*, nasal aperture; *op*, operculum; *pct.f*, pectoral fin; *ptg*, pterygopodia; *pv.f*, pelvic fin; *t*, teeth; *tc*, tactile flap; *v.f*, ventral fin. (A, after Cuvier; B, after Parker and Haswell.)

with their resemblances to the sharks, justify us in considering them an order under the Elasmobranchii. There are only three living genera, comprising about half a dozen species, and a few extinct genera, and they are all marine. One genus, the Chimæra, or sea cat (Fig. 290), occurs in Arctic and northern temperate waters, one in the Antarctic and southern temperate oceans, and one lives in the deep sea.

The general appearance of the body is sharklike except the head, while the skin is smooth, without scales. There are the typical shark fins well developed, with heterocercal tail, and claspers on the pelvic fins in the male. The head, however, is rather large, sometimes blunt, sometimes long and pointed, with a small mouth near the anterior end of the head, and only six teeth, four above and two below. There are only four gill slits, and, unlike the other Elasmobranchii, there is a fold of the skin, an operculum, which covers them so as to leave a single external opening on each side of the body. There is further no spiracle, and no cloaca; the anus opens on the surface of the body, and posterior to it is the opening of the urogenital ducts. The intestine is provided with a spiral valve as in the Selachii. The eggs are laid in horny capsules which are very large, in the northern genus about sixteen centimeters long, in the southern, twenty-five long by seven broad.

## SUBCLASS II. TELEOSTOMI

The Teleostomi (Gr. *τέλεος*, complete, and *στόμα*, mouth) include the great majority of fishes, both fresh-water and marine. They may be distinguished from the preceding groups of Vertebrata by the skeleton, which always consists wholly or partially of bone. The bones are formed in two ways; some replace the cartilaginous skeleton, while others are formed in fibrous connective tissue and are called membrane bones, or dermal bones, since they often develop in the deeper portion of the integument. The cranium is always more or less ossified, consisting of both cartilaginous and membrane bones; and bones develop in both the upper and lower jaws as a rule. The vertebræ are generally ossified, and are provided with dorsal outgrowths inclosing the spinal nerve cord and forming the neural arch, and with a pair of ventral processes, the ribs, forming the hæmal arch, and inclosing the viscera.

The surface of the body in the Teleostomi is sometimes covered with a naked skin, but more frequently with scales of various types, but never with placoid scales as in the Elasmobranchii. The unpaired fins are the dorsal, caudal, and ventral or anal; the dorsal and ventral vary much in size and number;

the caudal may be diphycercal, heterocercal, homocercal, or absent. Typically there are both pectoral and pelvic paired fins, and the latter are generally a considerable distance in front of the anus; they are not provided with claspers. The mouth is most frequently at the anterior extremity of the head, but it may be ventral and sometimes even dorsal. The five gill clefts never open directly to the outside, as in the Elasmobranchii, but are always covered by a fold of the skin, the operculum, which is supported by bony plates; there is thus left a single slitlike opening on each side of the head. There is no cloacal opening, but a distinct anus, and posterior to it the opening of the urogenital ducts.

The mouth is usually provided with teeth, sharp and recurved, and attached, not only to the jawbones, but to various bones on the roof of the mouth as well. There is a small tongue attached to the floor of the mouth. In some Teleostomi a spiral valve occurs in the intestine; in others there are tubular processes at the posterior end of the stomach, called the pyloric cæca, which vary in number from a single one up to two hundred. Frequently there lies just dorsal to the body-cavity an elongated sac, the air bladder or swimming bladder, which is sometimes a closed, gas-filled sac, and sometimes connects by a duct with the anterior part of the alimentary canal. It generally serves to facilitate the movement of the fish vertically through the water, but in some cases it may be respiratory. The kidneys lie just dorsal to the air bladder and ventral to the vertebral column. The reproductive organs are in the body-cavity; the sexes are separate as a rule, although there is one family hermaphroditic and self-fertilizing. Generally the Teleostomi are oviparous, but a few are viviparous. They may be divided into two groups, which for our present purpose may be called orders.

### Order 1. Ganoidei

The Ganoidei (Gr. *γάνος*, brightness, and *εἶδος*, appearance) are extensively represented among fossil fishes, but have only a few living species. They are essentially fresh-water fishes, although some are marine and ascend the rivers to spawn; the most common living representatives are the sturgeons and the

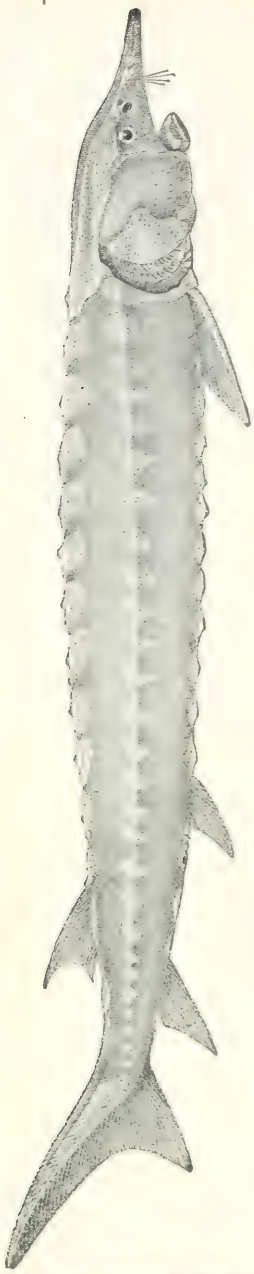

FIG. 291. *Acipenser sturio*, the sturgeon. (From Shipley and MacBride's Zoölogy.)

gar pikes. Structurally they form a connecting link between the Elasmobranchii and the Teleostei, the next order to be taken up. The common sturgeons, which belong to the genus Acipenser (Fig. 291), are the largest fresh-water fishes. They occur in North America and Europe, and some of the European species may attain a length of over seven and a half meters and a weight of some 1360 kilos.

They have an elongated snout with a toothless mouth on the ventral side of the head; anterior to the mouth are four barbels, soft, dependent processes. Over each eye is a spiracle, and five longitudinal rows of bony plates, or scutes, extend backward along the dorsal and lateral portions of the body. There is a dorsal fin, a ventral fin, and a heterocercal caudal fin, and the usual pectorals and pelvics. On the anterior border of the fins of most of the Ganoidei are scales called fulcra; they are found in no other group of fishes. The skeleton is almost entirely cartilaginous. As in all the Ganoidei, there is a spiral valve in the intestine, and an air

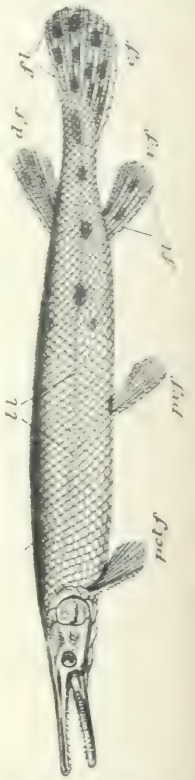


FIG. 292. [illegible] pike. *c*, caudal fin; *d.f.* dorsal fin; *fl.*, fulcra; *l.l.*, lateral line; [illegible] pectoral fin; [illegible] fin. [illegible] from Parker and Haswell's Text-book.)

bladder is present. The flesh of the sturgeons is eaten to a considerable extent, and the eggs are made into caviare; for this purpose the eggs of the sterlet, a small species about a meter in length, are considered the best. From the swimming bladder isinglass is made. The shovel-nosed sturgeons, genus Scaphirhynchus, have a flattened snout; one species occurs in the Mississippi and several others in Asia; it attains a length of about a meter and a half, and lacks the spiracles of the common sturgeon.

The gar pikes and their allies have a well-ossified skeleton and the surface of the body covered with enameled, rhombic scales, closely approximated to one another; these are called ganoid scales. The mouth is terminal, and the jaws are provided with teeth; in the common gar pike, *Lepidosteus osseus* (Fig. 292), the jaws are greatly elongated. It has been found only in America and is widely distributed in the United States, attaining a length of a meter and a half. The alligator gar of our Southern states grows to be twice as long. The spiral valve is very rudimentary, but the air bladder is highly developed and assists in respiration, like the lungs of the higher Vertebrata. The bowfin, *Amia calva* (Fig. 293), of the eastern United States is somewhat closely related to the gar pikes.

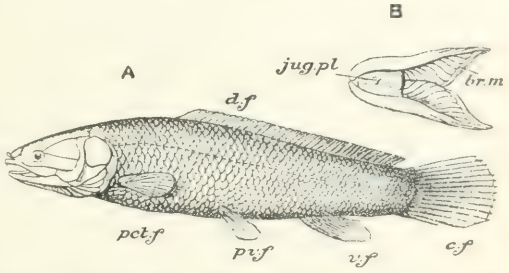


FIG. 293. *Amia calva*. The bowfin or mudfish. A, entire animal; B, ventral side of head. *br.m*, branchiostegal membrane; *c.f*, caudal fin; *d.f*, dorsal fin; *jug.pl*, jugular plate; *pct.f*, pectoral fin; *pv.f*, pelvic fin; *v.f*, ventral fin. (After Günther, from Parker and Haswell's Text-book.)

## Order 2. Teleostei

The Teleostei (Gr. τέλεος, complete, and ὀστέον, bone) include all the remaining fishes, except the three genera of the lungfishes to be considered later. The group derives its name from the skeleton, which is almost entirely of bone. In so large a group as this the variation in external form is necessarily enormous, as

is readily apparent when we recognize that such divergent types as the eel, the salmon, and the sea horse all belong here; but the general description of the external anatomy of the Teleostomi applies to the Teleostei, except that in place of the type of heterocercal tail characteristic of the Ganoidei, we find usually a homocercal tail with occasionally a diphycercal caudal fin or none at all. The body is sometimes covered with a naked skin, sometimes with bony plates, but usually with overlapping scales, which sometimes have a smooth, circular border and are called cycloid scales (Fig. 294), and sometimes have a toothed border and are known as ctenoid scales.

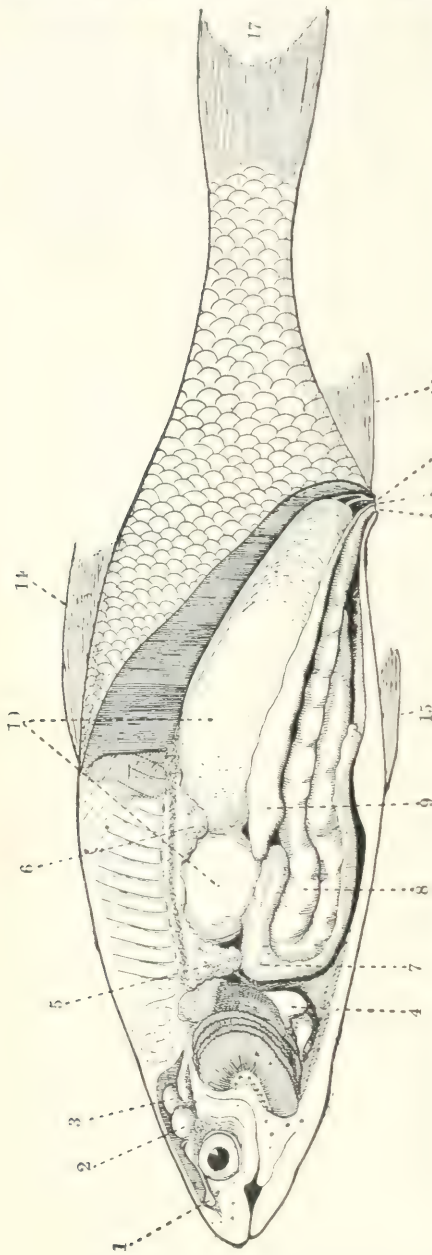


FIG. 294. *Lepidosteus osseus*, a pouch, dissected in part; slightly reduced. 1, olfactory lobe; 2, right optic lobe; 3, cerebellum; 4, heart, auricle; 5, lymphatic gland, the so called head kidney; 6, kidney; 7, liver; 8, intestine; 9, genital gland; 10, air bladder; 11, anus; 12, genital opening; 13, opening of ureter; 14, dorsal fin; 15, pectoral fin; 16, pelvic fin; 17, caudal fin. (After Shipley and MacBride.)

Internally the principal difference between the Ganoidei and the

Teleostei is found in the absence of a spiral valve in the intestine in the latter group; there is one exception to this rule. There are generally numerous pyloric cæca. A swimming bladder (Figs. 294 and 295) is usually present, and may or may not communicate by a duct with the alimentary canal. The sexes are separate with one exception, but occasionally in other species hermaphroditic individuals may be found; they are, of course, abnormal. In the female, the eggs in some cases pass into the body-cavity, and thence out through abdominal pores; in others they pass from the body-cavity into two tubes, the oviducts, which open posterior to the anus; and in still others the oviducts are directly continuous with the ovary, so that the ova do not enter the body-cavity at all.

Some Teleostei are viviparous, but the majority are oviparous, and the ova are generally deposited in the water, where they are fertilized. In some species they sink to the bottom, in others they float at the surface, others develop under the most various conditions: some fishes build nests; some attach their eggs to the under surface of rocks and stand guard over them; in some the ova pass into special brood pouches on the ventral side of the body of the male; others develop in the mouth cavity of the male; and in one species the ova sink into the soft skin on the ventral side of the female and remain there until developed. Fishes generally produce an enormous number of eggs, but only a relatively small percentage reach maturity, for both the ova and the young fishes are the favorite food, not only of many fishes, but of many other aquatic animals.

Many fishes may be readily raised artificially, and this is done to a large extent in the government fish commission stations in various parts of our country. The ova are obtained from the ripe female by compressing the abdomen between the thumb and first finger and sliding the fingers from the anterior toward the posterior end. The eggs are allowed to fall into a vessel of water, and are then mixed with the semen, or milt as it is called, obtained in the same way from the male fish. The fertilized eggs develop rapidly in shallow trays in running water, and when the young fry are sufficiently large they are transferred to the open water.

The Teleostei are very widely distributed, living in ponds,

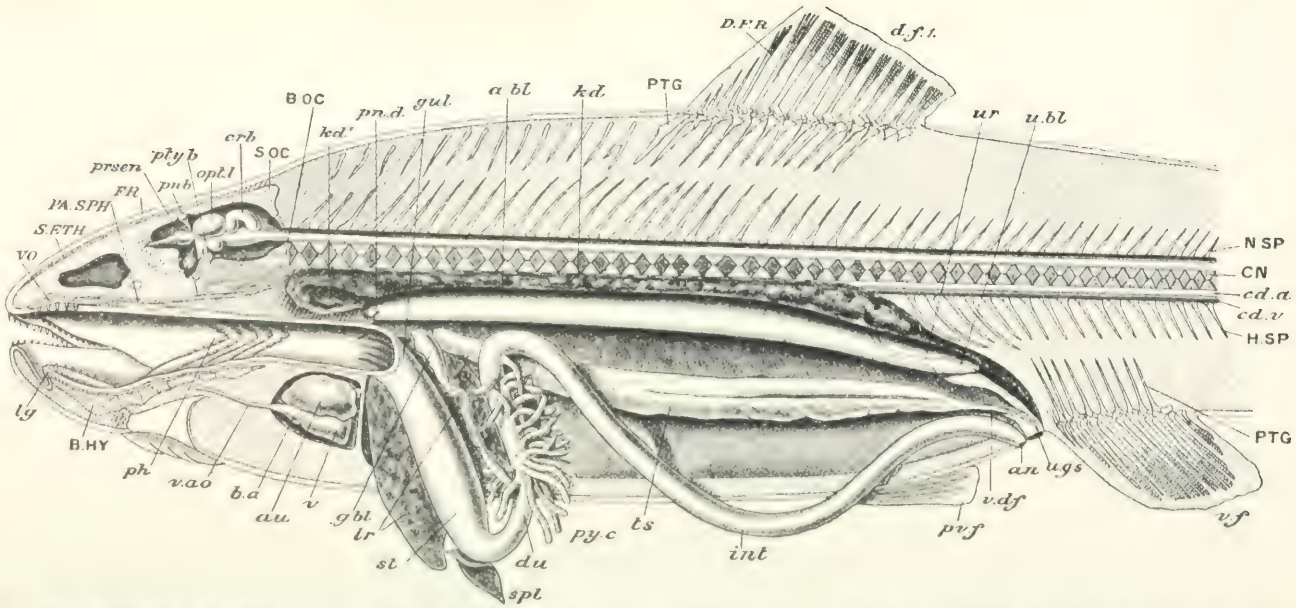


FIG. 295. *Salmo fario*, the brown trout; dissection from the left side. *a.bl*, air bladder, opened; *an*, anus; *au*, auricle; *b.a*, bulbus aortæ; *B.HY*, basi-hyal; *B.OC*, basi-occipital; *cd.a*, caudal artery; *cd.v*, caudal vein; *CN*, centrum; *crb*, cerebellum; *d.f.1*, first dorsal fin; *D.F.R*, dermal fin-rays; *du*, duodenum; *FR*, frontal; *g.bl*, gall-bladder; *gul*, gullet; *H.SP*, hæmal spine; *int*, intestine; *kd*, kidney; *kd'*, degenerate portion of kidney; *li*, liver; *N.SP*, neural spine; *opt.l*, optic lobes; *P.SPH*, parasphenoid; *ph*, pharynx; *pn.b*, pineal body; *pn.d*, bristle passed into pneumatic duct; *prsen*, prosencephalon; *pty.b*, pituitary body; *PTG*, pterygiophores; *pv.f*, pelvic fin; *pv.c*, pyloric cæca; *S.ETH*, supra-ethmoid; *S.OC*, supra-occipital; *sp*, spleen; *st*, stomach; *ts*, testis; *u.bl*, urinary bladder; *u.gs*, urogenital sinus; *ur*, ureter; *v*, ventricle; *v.ao*, ventral aorta; *v.df*, vas deferens; *v.f*, ventral fin; *VO*, vomer. (After Parker and Haswell.)

lakes, brooks, rivers, seas, and oceans the world over. Some of the marine fishes are littoral, living near the shore; others are pelagic, living near the surface in the open ocean; and still others are deep-sea species, only exceptionally seen near the surface. Some are confined to the north temperate and Arctic waters; some remain in the tropics; some migrate as the temperature of the water changes with the seasons. In the tropics the littoral or shore fishes are usually very brilliantly colored, particularly those living amongst the corals and algae. Thus they resemble their surroundings, and the bright colors and peculiar markings protect them from their enemies by rendering them less conspicuous. The pelagic fishes are generally a steel-blue above and whitish beneath. In the deep sea the colors are dull, but many deep-sea fishes are provided with spots or patches which give out a phosphorescent light, the only light in those regions, and by means of this light the fishes apparently see, as they have well-developed eyes.

Owing to the large number of species of Teleostei, and the fact that most people are more familiar with them than with other fishes, we can merely note here some which have an especial scientific, economic, or other interest.

The true eels, belonging to the genus Anguilla, differ from the typical fishes in having a greatly elongated, nearly cylindrical body. The dorsal and the ventral fins are continuous with the caudal fin. They are covered with small scales, and swim with great velocity. The eels spawn in salt water, and the very young are strikingly different from the adult, resembling the more typical fishes. The females ascend rivers and live there in the mud until they are ready to deposit their eggs; the males do not apparently go far from the sea. The conger eels are without scales and entirely marine; they are about twice the size of the common eel, and attain a length of nearly two meters. Related to the eels is the murry, with its formidable sharp teeth; it is found in the Mediterranean and the tropical waters of America.

The catfishes (Fig. 296), of which several species are found in the United States, have a variable number of long, soft processes, the barbels, attached to the jaws. The skin is entirely without scales, either naked or with bony plates. They are

mostly tropical, fresh-water fishes, though some are marine, varying in size from five centimeters to two meters, and are most abundant in South America; they are also numerous in the rivers of Africa. The common horned pout or bullhead of our Northern and Eastern states is not large, but a good food fish, and has been introduced into California; no catfishes are native west of the Rocky Mountains. The stone cats, about fifteen centimeters in length, are found in our South and West. The largest North American catfishes are the Great Lake cat-

Fig. 249. *Amiurus nebulosus*, a catfish, reduced. (From Shipley and MacBride's Zoology.)

fish, often exceeding fifty kilos in weight, and the Mississippi cat, which may weigh almost twice as much. The electric catfish of the Nile, *Malapterurus electricus*, can give a considerable electric shock like Torpedo, the electric ray. But the most powerful shock given by any fish is that of the electric eel of Brazil, *Gymnotus electricus*. It is eel-like in shape and attains a length of about two meters; the skin is entirely naked, without scales.

The carp family, Cyprinidæ, is a very large family of fresh-water fishes, distributed over the whole world except South America, Australia, and the Polar regions. They are of little value as food, but many are favorites in the ponds of private and public parks, particularly the goldfishes, natives of China, which retain their gold color only under domestication. If allowed to live wild in open streams, they revert to their natural olive color. The sardines, little marine fishes related to the herrings and the anchovies, are preserved in oil in southern Europe in great numbers; this is considered the best sardine, but the California sardine, a related species, is also of consider-

able importance, and has a wide distribution in the Pacific. The "American sardine," so extensively put up in tins on the Atlantic seacoast of the United States, is the young menhaden, belonging to a different genus. In a related family is the huge *Arapaima gigas*, found in the rivers of Brazil and Guiana, and not exceeded in size by any strictly fresh-water teleost. It attains a length of from four to five meters, weighing two hundred kilos, and is said to be a good food fish.

Not far removed from the last two groups is the large family, Salmonidæ, to which the various kinds of salmon and trout belong. They are widely distributed in the north temperate and Arctic regions of both continents. Some, like the whitefish, live mostly in lakes; others, like the grayling and trout, are found in clear, cold brooks; others, like the salmon, are marine, and ascend the rivers to spawn. The salmon is one of the most important food fishes in the United States and very important

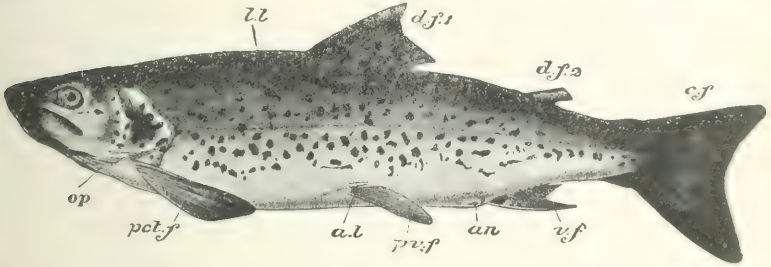


FIG. 297. *Salmo fario*. *a.l*, adipose lobe of pelvic fin; *an*, anus; *c.f*, caudal fin; *d.f.1*, first dorsal fin; *d.f.2*, second dorsal or adipose fin; *l.l*, lateral line; *op*, operculum; *pct.f*, pectoral fin; *pv.f*, pelvic fin; *v.f*, ventral fin. (After Jardine, from Parker and Haswell's Manual.)

to the canning industry. The largest salmon is the quinnat, or king salmon, of the northern Pacific, *Oncorhynchus tschawytcha*, which sometimes ascends the rivers for a thousand or twelve hundred kilometers or more (six hundred to eight hundred miles) to spawn. They are killed to such an enormous extent by the canners that there appears to be great danger of their extinction. The salmon on our Atlantic coast is *Salmo salar;* it does not extend south of Cape Cod, but is found in northern Europe also. The land-locked salmon, found in some of our inland lakes and in Sweden, is now believed to belong to the same species: it never makes its way to the sea. Of the many species of trout,

a large number belong to this same genus Salmo; some are marine, others fresh-water (Figs. 297 and 298). One of the most widely distributed is the black-spotted trout of northern Europe, Asia, and America west of the Mississippi Valley. But no trout is equal to the brook trout, *Salvelinus fontinalis*, for gaminess; in England it is known as the charr, and is thus distinguished from the members of the genus Salmo. It frequents clear, cold mountain streams and lakes in the northern portions of both continents, except in the Rocky Mountain region. In the United States it occurs only east of the Mississippi, from northern Georgia northward. Unfortunately it is fast disappearing; it is the favorite game fish of America, and sought after by every lover of true sport.

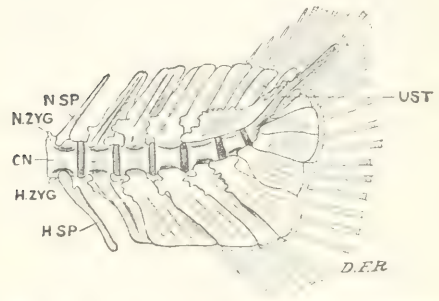


FIG. 298. *Salmo trutta*. Caudal end of vertebral column. *CN*, centrum; *D.F.R*, dermal fin-rays; *H.SP*, hæmal spine; *H.ZYG*, hæmal zygapophysis; *N.SP*, neural spine; *N.ZYG*, neural zygapophysis; *UST*, urostyle. (After Parker and Haswell.)

The North Atlantic supplies a large number of excellent food fishes, such as the bluefish, found off our eastern coast; the pompano, one of our choicest Southern fishes; the mackerel, which moves in large schools and is taken by seines or by lines; the Spanish mackerel, which is found along our Southern coast; the swordfish, widely distributed in temperate waters; the red snapper of Florida, one of our best Southern fishes; the striped

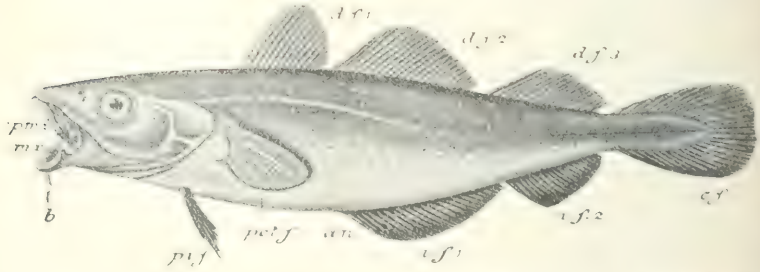

FIG. 299. *Gadus morrhua*, the cod. *an*, anus; *c.f*, caudal fin; *d.f.1, 2, 3*, dorsal fins; *mx*, maxilla; *pct.f*, pectoral fin; *pmx*, premaxilla; *pv.f*, pelvic fin; *v.f.1, 2*, ventral fins. (After Cuvier, from Parker and Haswell's Text-book.)

bass, which extends from the Gulf of St. Lawrence to Florida; the tautog, or blackfish, found from Maine to South Carolina; the true codfish, *Gadus morrhua* (Fig. 299), found in the cold waters of the whole northern hemisphere, and its relative the haddock, which is confined to the North Atlantic. The average weight of a cod is about five kilos and of a haddock two, but much larger specimens are on record. In the northern Pacific is a good food fish, *Ophiodon elongatus*, known in San Francisco as the codfish, which, however, is not related to the Atlantic cod. The tunny, or horse mackerel, as it is called in Massachusetts, is a large marine fish, averaging from two to three meters in length, and weighing from one hundred to two hundred and fifty kilos, although specimens twice that size and three times that weight are recorded. It is found on both sides of the Atlantic, and is largely eaten in Europe, but in America is used chiefly for its oil.

Many of the flatfishes (Fig. 300), also marine, are largely used as food, such as the flounder, turbot, sole, and plaice, and especially the halibut, the largest of all. It is abundant on both the

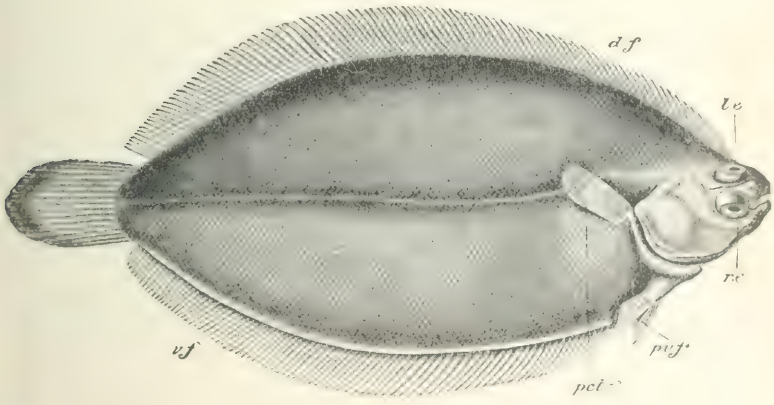


FIG. 300. *Pleuronectes cynoglossus*, from the right side. *d.f*, dorsal fin; *l.e*, left eye; *pct.f*, pectoral fin; *pv.f*, pelvic fin; *r.e*, right eye; *v.f*, ventral fin. (After Cuvier, from Parker and Haswell's Manual.)

east and west coasts of the United States, frequenting cold waters of from four hundred to five hundred meters in depth. The female flounder is much more desirable as food than the male, and averages from fifty to seventy-five kilos in weight.

When small, weighing from five to ten kilos, they are known as chicken halibut, and are especially good. All of these flatfishes live on the bottom, and are interesting because of the curious asymmetry of the head. The body is greatly compressed laterally, and one side is light in color, the other darker; the animal lies on its lighter side, and both eyes are on the darker side, the right or the left, as the case may be. The very young flatfish is strictly bilaterally symmetrical, like any other fish, with one eye on each side of its head, and swims vertically in the water. But later it lies on one side on the bottom, and the eye which is beneath slowly migrates until it comes to lie on the same side of the head as the other. In connection with food fishes we should mention the black bass, a fresh-water fish, which has a wide distribution in the United States, and is considered one of the finest game fishes. It is confined to America, and by some English sportsmen is considered superior to the trout.

FIG. 301. *Gasterosteus pungitius*, the stickleback; nest. (After Landois, from Claus and Sedgwick's Text-book.)

There remain a number of fishes interesting for some peculiarity of structure or habit. The sticklebacks are small fishes, some marine and some fresh-water, found in both Europe and America, whose chief interest centers in the nest which the male builds for the eggs (Fig. 301). This nest consists of bits of plants which the fish cements together with the secretion from a gland opening just in front of the anus. The nest has two openings, so that the fish may swim through; the eggs are deposited in layers by several females, and the male fertilizes each set as it is laid.

In India there are fishes provided with respiratory chambers near the gills; by means of these chambers they can breathe air directly, and so live in moist places on land; further, if kept under water and the respiratory chamber becomes filled with water, they are likely to die. Closely related to these air-breathing fishes is the climbing fish, *Anabas scandens* (Fig. 302), which by means of its operculum is able to climb up the sides of wet palm trees for a distance of a couple of meters.

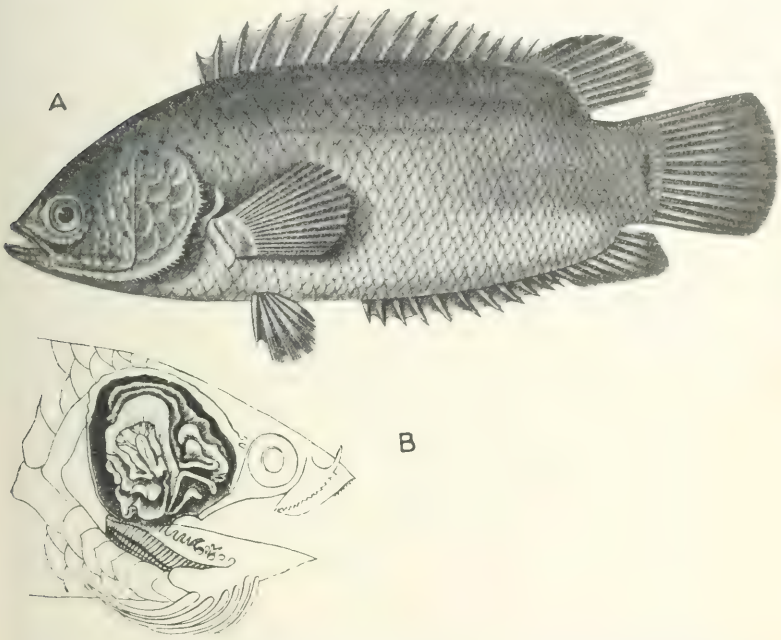


FIG. 302. *Anabas scandens*, the climbing perch. A, entire animal; B, head dissected to show accessory respiratory organ. (A, after Cuvier; B, after Günther. From Parker and Haswell's Text-book.)

A curious fish living at a depth of about three thousand meters, it is said, is the black swallower, *Chiasmodon niger*; owing to the great distensibility of its stomach and ventral body wall it is capable of swallowing fishes much larger than itself. The suckfish, *Remora remora*, is found in tropical waters; it has a suckerlike plate on the top of its head by means of which it can attach itself to various objects. With a ring fastened to their tail, and a line, they are used by African fishermen for

catching other fish. A deep-sea fish sometimes thrown up on the Scandinavian or British coast is the oarfish, *Regalecus banksii*, a very flat, bandlike fish, attaining a length of seven meters, which has probably given rise to several sea serpent fables.

The curious marine pipe fishes and sea horses (Fig. 303) are interesting because of the pouch which is present on the ventral side of the male. The eggs are introduced into this pouch and there develop, the young remaining until they are capable of taking care of themselves. The sea horse is without

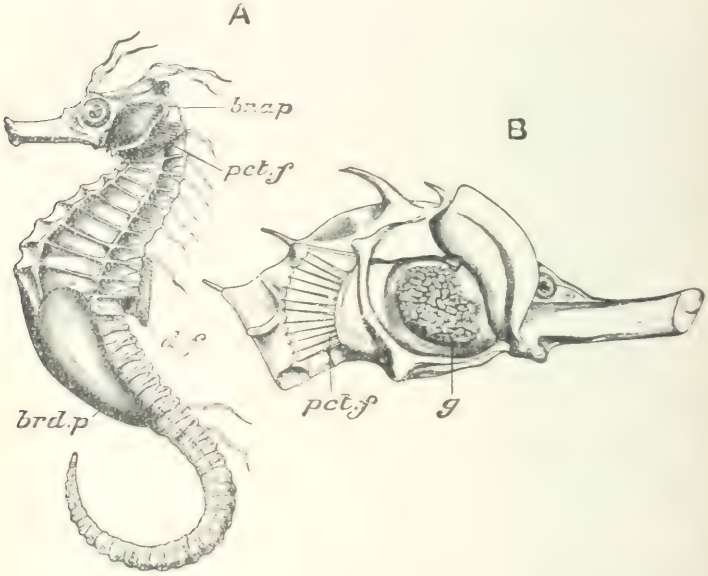


FIG. 303. *Hippocampus*, a sea horse. In B, the operculum is raised to show the gills. *brap*, branchial aperture; *brd.p*, brood pouch; *d.f*, dorsal fin; *g*, gills; *pct.f*, pectoral fin. (From Parker and Haswell's Manual.)

a caudal fin, and when at rest it coils its tail about a stick or water plant and thus anchors itself; when in motion the body remains vertical in the water.

Other curious fishes are the swellfishes and globefishes, which can distend their bodies enormously; the sunfish, a big, flat fish, two and a half meters long, and weighing nearly four hundred kilos, which floats on the surface of the temperate waters both North and South; and the angler, or goosefish, *Lophius piscatorius* (Fig. 304), abundant on the coast of New England; it lies

on the bottom, where its form and coloring closely resemble surrounding objects, with its huge mouth open, ready to swallow any unwary animal that approaches. The story that it uses its dorsal spine with leaflike appendage as a bait for other fishes is probably a zoological fable. The egg mass of the goosefish is an interesting object. Each egg is inclosed in a transparent

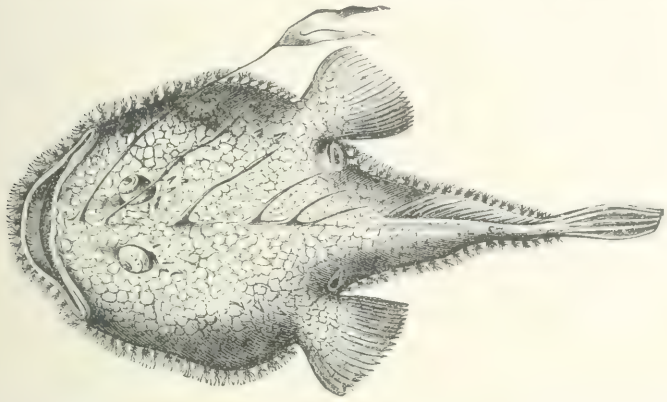

FIG. 304. *Lophius piscatorius*, variously known as the angler, frogfish, goosefish; much reduced. (After Cuvier and Valenciennes, from Coues and Sedgwick's Text-book.)

gelatinous capsule, and these adhere together, forming a band, thirty or more centimeters wide and ten meters long, of purplish color, which floats near the surface of the water. In the waters about the Philippines lives a fish scarcely two centimeters in length; it is of interest as being the smallest known living vertebrate.

## SUBCLASS III. DIPNOI

The Dipnoi (Gr. δίς, double, and πνοός, breathing), or lungfishes, have only three living genera. They are fishlike or eellike in appearance, with dorsal and ventral fins continuous with the caudal, and both pectoral and pelvic fins present. The body is covered with large cycloid scales, and an operculum incloses the gills. The skeleton is partly ossified. A spiral valve is present in the intestine, and there are abdominal pores and a cloaca. An air bladder is always present, which may perform the function of a lung, and is provided with a duct, which opens into the pharynx on its ventral side.

The three genera are widely separated geographically. One, Ceratodus (Fig. 305), is found in the rivers of Australia; the lung is single. It attains a length of two meters, and its pink flesh is considered an excellent food by the natives. A second genus, Lepidosiren (Fig. 306), is found in Brazil and Paraguay. It may grow to a length of about a meter and a third; it is provided with a pair of lungs. The third genus, Protopterus (Fig. 307), is quite abundant in the rivers of tropical Africa. It is carnivorous, may

FIG. 305. *Ceratodus forsteri*, much reduced. (After Günther, from Parker and Haswell's Manual.)

FIG. 306. *Lepidosiren paradoxa*, the lungfish of South America; male, with fringed pelvic fins of the breeding season. (From Shipley and MacBride's Zoölogy.)

FIG. 307. *Protopterus annectens*, the lungfish of Africa. (After Claus and Sedgwick.)

attain a length of nearly two meters, and just before the dry season buries itself in the mud, where it remains coiled up and quiescent until the return of moisture. The remains of fossil Dipnoi are abundant in Europe and America. These fishes are of considerable importance, as they are believed to form a connecting link between the lower fishes and the next class of vertebrata to be considered, the Amphibia.

## CLASS III. AMPHIBIA

The Amphibia (Gr. *ἀμφί*, both, and *βίος*, life) are familiar through such representatives as the salamanders, frogs, and toads. As a rule they pass through a larval stage in the water, and in the adult condition may live upon land, although many remain in the water all their lives. They are found in fresh water, never in salt. The body is covered with a soft, naked skin, except in one group, which possesses minute scales, but some of the extinct Amphibia were provided with well-developed bony plates in the integument. Some extinct species were gigantic in size; in one the skull alone was over a meter and a half long. The skin contains numerous glands, which by their secretions keep it moist while out of the water. In some species the secretion is poisonous to other animals. The outer layer of the skin is shed periodically.

Many Amphibia which possess tails, such as the hellbender and mud puppy of our Central states, are strikingly fishlike in appearance. There is an unpaired fin on the dorsal side, continuing about the diphycercal tail and along the posterior part of the ventral side, like the median fin of the Dipnoi, the true eels, and some other fishes. But this fin is never provided with skeletal supports, or fin-rays, as in the fishes. The great difference externally between such Amphibia and the fishes is found in the paired appendages, which here are never fins, but pentadactyl extremities, or legs. As a rule there are two pairs of these, anterior and posterior, or pectoral and pelvic; but in a few cases only the anterior pair is present, and in a few both pairs are absent. These appendages are provided with an internal bony skeleton, and the arrangement of the bones is on the same plan in this and all the higher groups of Vertebrata;

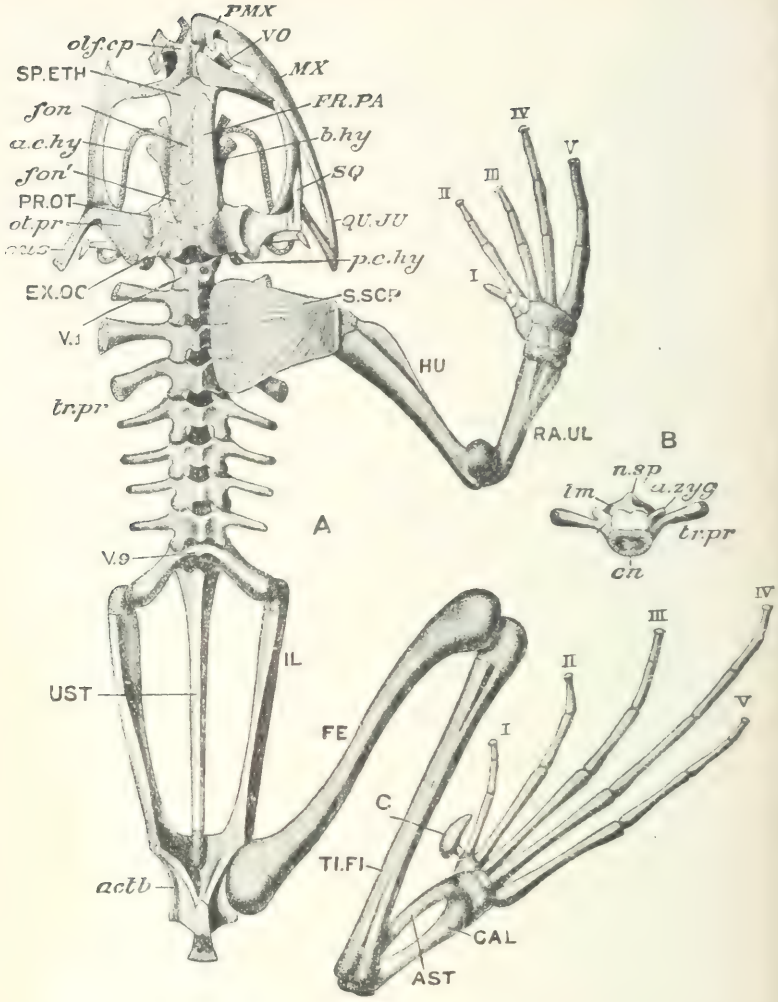


FIG. 308. *Rana temporaria*, the common European frog. A, dorsal aspect of skeleton; on the left half the membrane bones of the skull, the shoulder girdle and the fore and hind limbs have been removed. Cartilaginous parts dotted. Names of cartilage bones in thick capitals, of membrane bones in italic capitals. *a.c.hy*, anterior cornu of hyoid; *actb*, acetabulum; **AST**, astragalus; *b.hy*, basi-hyal; **C**, calcar; **CAL**, calcaneum; **EX.OC**, exoccipital; **FE**, femur; *fon*, *fon'*, fontanelles; *FR.PA*, fronto-parietal; **HU**, humerus; **IL**, ilium; *MX*, maxilla; *olf.cp*, olfactory capsule; *ot.pr*, otic processes; *p.c.hy*, posterior cornu of hyoid; *PMX*, premaxilla; **PR.OT**, pro-otic; *QU.JU*, quadrato-jugal; **RA.UL**, radio-ulna; **SP.ETH**, sphenethmoid; *SQ*, squamosal; **S.SCP**, supra-scapula; *sus*, suspensorium; **TI.FI**, tibio-fibula; *tr.pr*, transverse process; **UST**, urostyle; **V.1**, cervical vertebra; **V.9**, sacral vertebra; *VO*, vomer; I–V, digits. B, the fourth vertebra, anterior aspect; *a.zyg*, anterior zygapophysis; *cn*, centrum; *lm*, lamina; *n.sp*, neural spine; *pd*, pedicle; *tr.pr*, transverse process. (After Howes, slightly altered, from Parker and Haswell's Manual.)

the same is true of the pectoral and pelvic girdles, composed of bones to which the appendicular skeleton is attached; these girdles are more or less intimately connected with the axial skeleton. The skull and vertebral column are bony, but the ribs are very rudimentary (Fig. 308).

All of the Amphibia are provided with gills, three pairs of soft processes or outgrowths of the integument rich in blood vessels and known as the external gills, such as occur in some

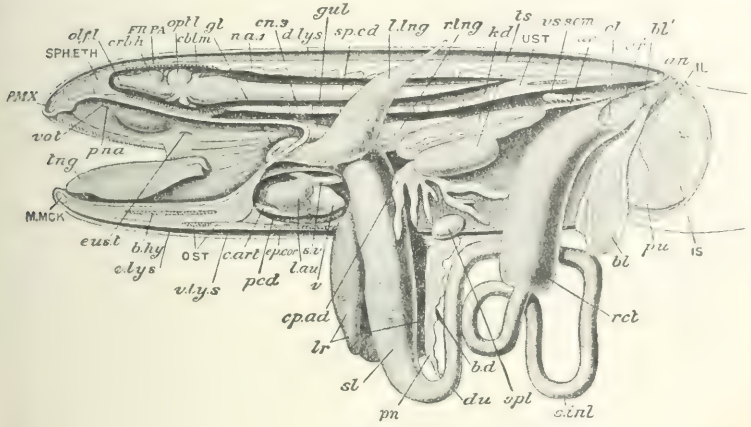


FIG. 309. *Rana temporaria.* Dissection from the left side; the viscera somewhat displaced. *an*, anus; *b.d*, bile duct; *b.hy*, body of hyoid; *bl*, urinary bladder; *bl'*, its opening into cloaca; *c.art*, cornus arteriosus; *cblm*, cerebellum; *cl*, cloaca; *cn.3*, centrum of third vertebra; *cp.ad*, corpus adiposum; *crb.h*, cerebral hemisphere; *d.ly.s*, dorsal lymph sinus; *du*, duodenum; *ep.cor*, epicoracoid; *eus.t*, Eustachian tube; *FR.PA*, fronto-parietal; *gl*, glottis; *gul*, gullet or œsophagus; *IL*, ilium; *IS*, ischium; *kd*, kidney; *l.au*, left auricle; *l.lng*, left lung; *lr*, liver; *M.MCK*, mento-meckelian; *n.a.1*, neural arch of first vertebra; *olf.l*, olfactory lobe; *opt.l*, optic lobe; *O.ST*, omo- and epi-sternum; *pcd*, pericardium; *PMX*, premaxilla; *pn*, pancreas; *p.na*, posterior naris; *pu*, pubis; *rct*, rectum; *r.lng*, right lung; *s.int*, small intestine; *sp.cd*, spinal cord; *SPH.ETH*, sphenethmoid; *spl*, spleen; *st*, stomach; *s.v*, sinus venosus; *tng*, tongue; *ts*, testis; *ur*, ureter; *ur'*, its opening into the cloaca; *UST*, urostyle; *v*, ventricle; *v.ly.s*, ventral lymph sinus; *vo.t*, vomerine teeth; *vs.sem*, vesicula seminalis. (After Parker and Haswell.)

fishes, but only in the embryonic condition for the most part. In some cases these gills persist throughout life, but in the majority they disappear, and respiration is then carried on by means of lungs as in the higher Vertebrata. Some Amphibia have neither gills nor lungs, and in these respiration takes place through the skin and through the wall of the pharynx, which in such cases is provided with numerous blood vessels. The direct respiration of air is accompanied by a

modification of the nasal chamber, which now has not only an external opening, but also an internal opening into the mouth or pharynx.

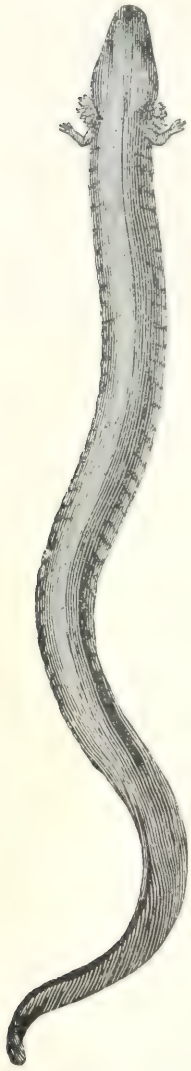

FIG. 310. *Siren lacertina*. (From Parker and Haswell's Textbook.)

The eyes are kept moist while the animal is on land by means of structures like eyelids, and the ears in the higher Amphibia show a decided advance in development over the condition in fishes. They are now distinctly organs of hearing, and have an eardrum, or tympanic membrane, on a level with the surface of the skin, and familiar to every one as the flat circular disc on the sides of a frog's head. The chamber within this tympanum connects with the posterior part of the mouth by a tube, the Eustachian tube, just as in all the higher Vertebrata.

In the lower Amphibia the tongue is rudimentary; in some it is absent. In the higher groups it is attached at the anterior end of the floor of the mouth and its free, posterior end is bifid and can be thrown out to catch insects and other small animals which serve as food. Many can live a long time without food and hibernate during the winter in the mud at the bottom of streams and ponds. The intestine and the urogenital ducts open into a cloaca, so that there is a single opening at the posterior end of the body, the cloacal opening (Fig. 309). The sexes are always separate. The eggs are usually laid and fertilized in the water, and develop independently without any care from the parents; the few exceptions will be mentioned later. The living Amphibia may be divided into three subclasses, or orders, as they are often called.

### SUBCLASS I. URODELA

The Urodela (Gr. οὐρά, tail, and δῆλος, distinct) include all Amphibia which have a tail in the adult condi-

tion. They are found almost exclusively in the northern hemisphere. In some the gills persist throughout life, and they are naturally aquatic in habit. This is true of the genus Siren (Fig. 310), the mud eel of our Southern states, and also of Necturus

FIG. 311. *Necturus maculatus*. br, gills; br.cl, gill clefts; an, anus. (After Parker and Haswell.)

(Fig. 311), the mud puppy of our Central states. In some the external gills have disappeared, but the gill slits persist and communicate with the outside by a cleftlike opening in the neck region. Examples of this condition are found in the Congo eel, Amphiuma (Fig. 312), of our Southern states, and the hellbender, or water dog, *Protonopsis horrida*, of the Ohio river, salamander-like in appearance, and said to be excellent as food. The latter ranges from thirty to sixty centimeters in length and is entirely harmless. Closely related to these two is the giant

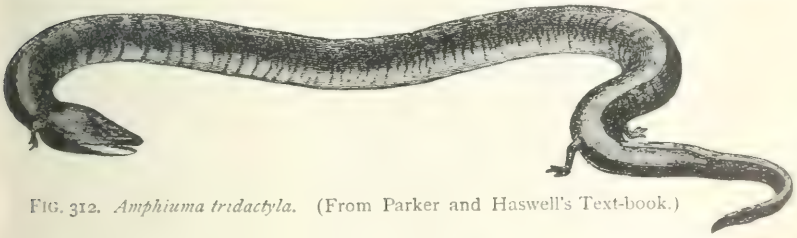

FIG. 312. *Amphiuma tridactyla*. (From Parker and Haswell's Text-book.)

salamander of Japan and Thibet, *Megalobatrachus maximus*, which attains a length of nearly a meter; it is the largest living amphibian.

Finally there are the true salamanders in which neither external gills nor gill slits are present in the adult. Some are confined to Europe, as the yellow-spotted salamander, *Salamandra maculosa*, and the smaller, black *Salamandra atra*, which are noteworthy because they are viviparous, a very exceptional condition in the Amphibia. Our common newt belongs to the genus Dienmyctylus, which is widely distributed over the whole northern

hemisphere. The genus Amblystoma is interesting because in some species its larva, known technically as siredon, remains for a long time in the larval condition, with external gills, and even becomes sexually mature in that stage. *Amblystoma maculatum* is known commonly as axolotl by the Mexicans and is eaten by them.

## SUBCLASS II. ANURA

The Anura (Gr. *ἀ*, without, and *οὐρά*, tail) consist of the frogs and toads, and are tailless in the adult condition. They are sometimes known as Batrachia (Gr. *βατράχιος*, froglike), and this term is sometimes applied to the whole group of Amphibia as well. They are widely distributed over the whole world. The respiration is by lungs in the adult; the internal nares are at the anterior end of the mouth, and the air passing into the mouth cavity is forced into the lungs by a swallowing movement; the larvæ, as in all other Amphibia, are provided with gills.

FIG. 313. *Pipa americana*, ♀, the Surinam toad. (From Parker and Haswell's Text-book.)

A few species are tongueless; of these the best known is a toad, *Pipa americana* (Fig. 313), found, so far as we know, only in South America. Its method of caring for its developing eggs is pretty generally known. The male places the eggs on the dorsal surface of the female, and after they are fertilized, the skin grows up around each egg, forming a chamber for it; over this chamber a lid, or operculum, develops, and within the cell thus formed the egg develops into a young toad; after it leaves the cell, the skin of the female resumes its former normal condition.

All other toads have tongues; in some, as in the family Bu-

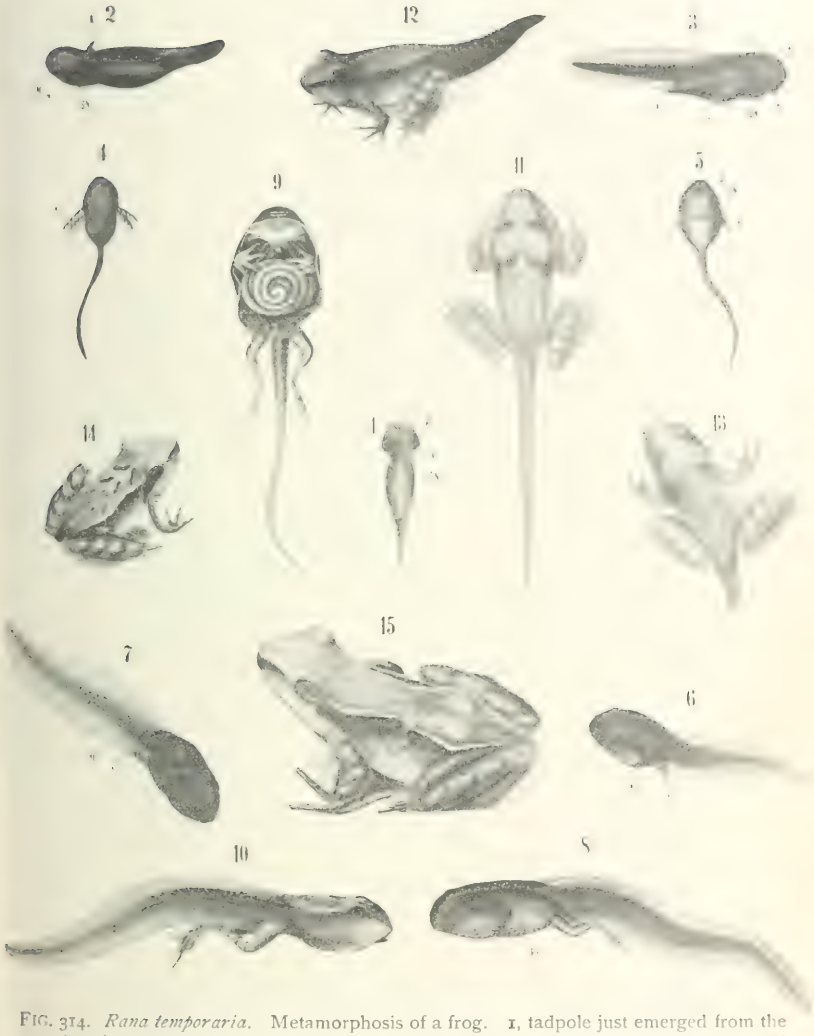


FIG. 314. *Rana temporaria.* Metamorphosis of a frog. 1, tadpole just emerged from the egg, dorsal aspect; 2, 3, successively older tadpoles, later aspect; 4, slightly older, dorsal aspect; 5, still older, ventral aspect; 6, gills completely covered by membrane, leaving a single external opening on the left side; 7, first indication of hind legs; 8 and 10, successively older stages; 9, about the same age as 10, with ventral body wall removed, showing gills, front legs, and coiled intestine; 11, with both pairs of legs free; 12 and 13, successive stages in the absorption of the tail; 14, tail completely absorbed; 15, adult frog. *A*, anus; *HE*, hind leg; *K*, gills; *KL*, gill opening; *M*, mouth; *N*, nasal opening; *O*, eye; *SN*, sucker. (Photographed from a Leuckart-Nitsche wall chart, by the author; permission of Dr. C. Chun.)

fonidæ, the jaws are toothless and the skin is generally rough and warty. They are most abundant in the tropics, but are distributed over the whole world The largest of all is *Bufo marinus*, of tropical America, whose head and body attain a length of twenty centimeters. Almost as large is the *Bufo boreas* of the Pacific slope of North America. The common toad of our Middle, Northern, and Western states is *Bufo americanus*, whose musical note is heard in the spring and summer. Related to these is the *Bombinator igneus* of Europe and Asia, which is aquatic in habit. Another European toad, *Alytes obstetricans*, is of interest because the male places the eggs, which are laid in a long, gelatinous string, on his back and winds them about his hind legs; there they remain until they have developed. The true tree toads belong to the family Hylidæ and are most numerous in tropical America; they are provided with teeth and many are brilliantly colored. The most common in the United States is *Hyla pickeringii*, whose shrill note is very noticeable in the springtime.

The frogs, like these toads, have a well-developed tongue, and, while some are toothless, the true frogs have teeth in the upper jaw; they likewise have the hind legs developed for leaping, and a smooth skin. The largest is our North American bullfrog, *Rana catesbiana*, whose head and body attain a length of twenty centimeters. There are several smaller species of this same genus in Europe and many in this country. The eggs of frogs are inclosed in a transparent, gelatinous envelope and adhere together in irregular masses unlike the long strings of the toad's eggs; they may be found in almost any body of quiet water near the shore in the spring and early summer, and rapidly develop into the larvæ or tadpoles (Fig. 314).

## SUBCLASS III. GYMNOPHIONA

The Gymnophiona (Gr. γυμνός, naked, and ὄφις, serpent) are vermiform Amphibia, without appendages and tailless, with the skin folded so that the animal appears ringed much like an earthworm; minute scales are present in the integument. The eyes are very rudimentary and covered by the skin, while some species are blind. They are found in tropical portions of South

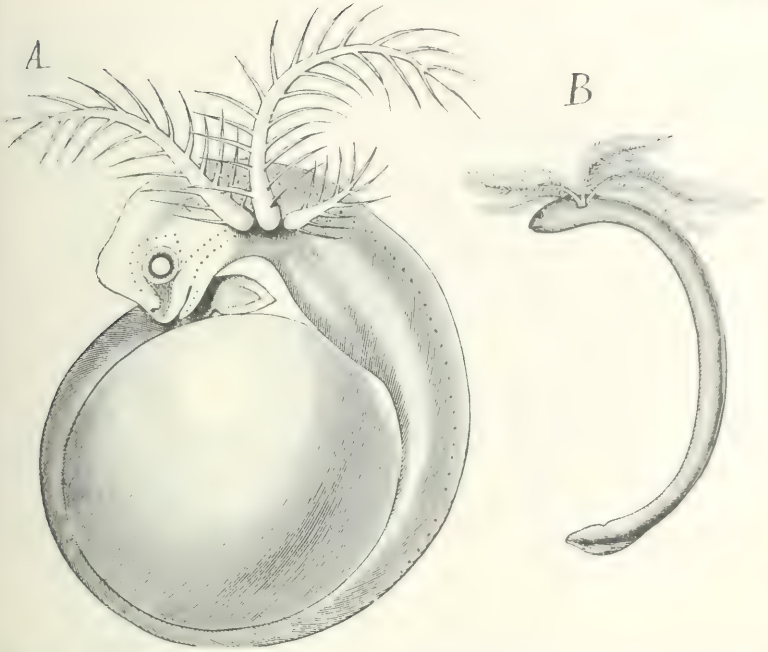


FIG. 315. *Epicrium glutinosum*, one of the **Gymnophiona**; larva, with external gills. A, earlier stage, with large yolk mass; B, more advanced. (After Sarasin, from Parker and Haswell's Text-book.)

America, Africa, and the East Indies, where they burrow in the earth and feed on worms and the larvæ of insects. Their relation to the other Amphibia is recognized in part from their internal structure, and chiefly from their development, since a larva is produced provided with external gills (Fig. 315). They are known generally as cæcilians, from the name of one of the genera (Fig. 316).

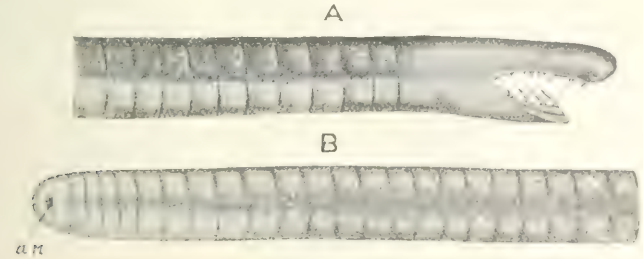


FIG. 316. *Cæcilia pachynema*, one of the **Gymnophiona**. A, anterior extremity from the right side; B, posterior extremity from the ventral side. *an*, anus. (After Boulenger, from Parker and Haswell's Text-book.)

## CLASS IV. REPTILIA

The Reptilia (Lat. *repere*, to crawl) are cold-blooded animals like the fishes and amphibians; from the former they may be distinguished by the absence of gills, and from the latter by the outer covering of the body, which is never soft, but has a hard, horny surface, often scaly; there are frequently bony plates in the deeper part of the integument as well, and no glands for the most part. Although many reptiles live a good part of the time in water, they are as a group essentially land animals and breathe exclusively by means of lungs. Each individual is provided with a pair of lungs, but in the greatly elongated species the left lung becomes rudimentary and may almost disappear. In the serpents and some lizards there are no appendages, but most lizards, as well as the turtles and crocodiles, possess two pairs, well adapted to walking and with claws on the ends of the digits; the appendages are also well developed in fossil reptiles.

The eyes are provided with lids, except in the serpents and some lizards, where they are covered by the skin, which there becomes thin and transparent; this skin represents the fused eyelids. In many lizards a sort of third eye is present, median in position on the dorsal side of the head; it is connected by a stalk with the brain and is covered with a transparent scale. This third eye is called the parietal or pineal eye, and a similar structure occurs in the brains of all the other classes of vertebrates, but in no case is it so highly developed as here. The organs of smell and hearing are usually well developed.

Teeth are present in all reptiles except turtles, and are sharply pointed and often recurved; they merely serve for holding the prey and not for mastication. In the poisonous serpents one pair of teeth in the upper jaw is deeply grooved or even tubular and serves to convey the poison to the victim. In most reptiles there are glands in the mouth, called salivary glands, and some of these are modified in certain serpents into poison glands. The tongue is slender, bifid, and protrusible in the serpents and most lizards; in other reptiles it is flat and immovable, attached to the floor of the mouth. The alimentary canal terminates in a cloaca, which also receives the ureters or ducts from the kidneys, and also the ducts from the reproductive organs. In the

lizards and turtles there is a urinary bladder attached to the ventral wall of the cloaca; it is absent in the snakes and

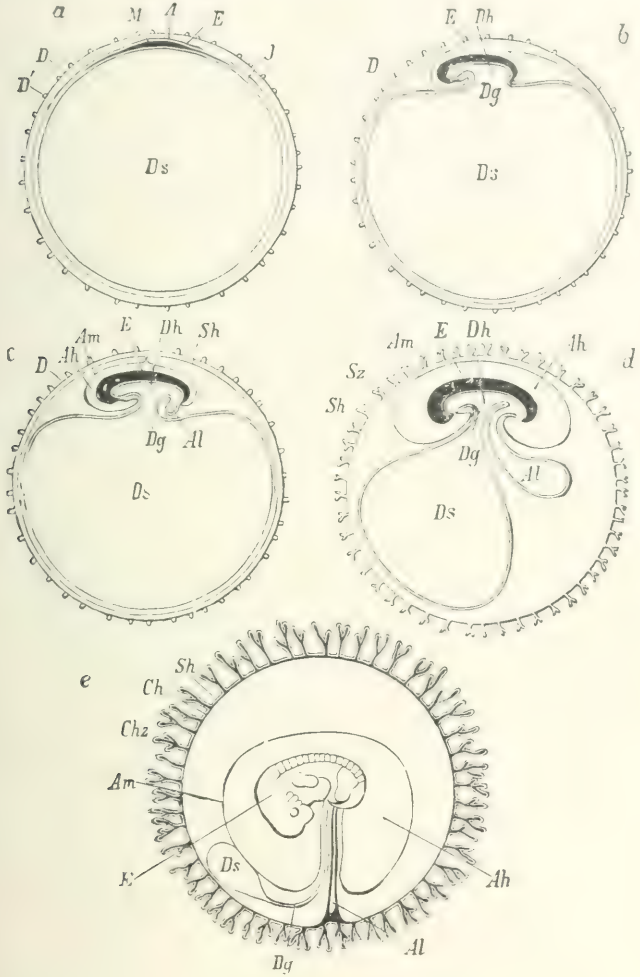


FIG. 317. Diagrams illustrating the formation of the fœtal membranes of a mammal. *a*, ovum with the embryo just beginning to develop; *b*, ovum with embryo in longitudinal section and developing amnion; *c*, ovum with amnion closing and developing [illegible]; *d*, embryo with mouth and anus; villous serosa; *e*, chorion in contact with serosa; yolk sac reduced, amniotic cavity enlarged. *A*, ectoderm; *Ah*, amniotic cavity; *Al*, allantois; *Am*, amnion; *Ch*, chorion (vascular layer of allantois); *Chz*, chorionic villi (consisting of chorion and serosa; *D*, zona radiata; *D'*, villi of zona; *Dg*, umbilical stalk; *Dh*, intestinal cavity; *Ds*, cavity of embryonic (blastodermic) vesicle, later of the yolk sac (umbilical vesicle); *E*, embryo; *J*, entoderm; *M*, mesoderm; *Sh*, serosa; *Sz*, villi of serosa. (After Kölliker, from Claus and Sedgwick's Text-book.)

crocodiles. A copulatory organ or penis is present; in the lizards and serpents there are two penes, one on each side of the median line of the cloaca; in the turtles and crocodiles there is only one.

Most reptiles are oviparous, but some lizards and snakes are viviparous. The eggs resemble birds' eggs; they have a large amount of yolk and are inclosed in a membranous or calcareous shell. In the course of development a membrane grows around the embryo, completely inclosing it (Fig. 317). This membrane

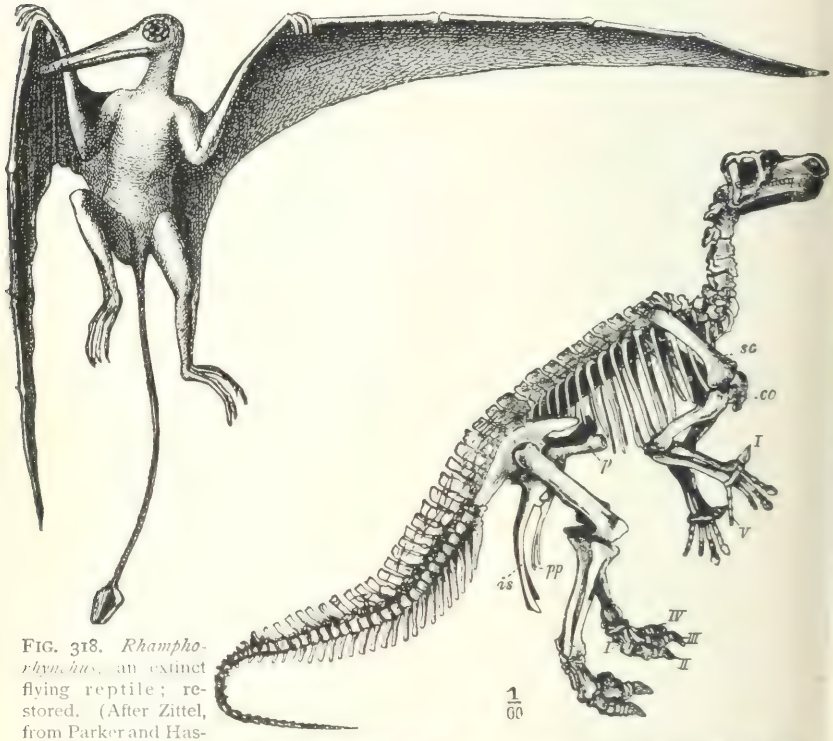


FIG. 318. *Rhamphorhynchus*, an extinct flying reptile; restored. (After Zittel, from Parker and Haswell's Text-book.)

FIG. 319. *Iguanodon bernissartensis*, one sixtieth natural size. *co*, coracoid; *is*, ischium; *p*, pubis (pectineal process); *pp*, postpubic process (pubis); I–IV, I–V, digits. (After Dollo, from Parker and Haswell's Text-book.)

is called the amnion, and the space between it and the embryo is filled with a fluid, the amniotic fluid. This amnion occurs in the development of the birds and the mammals also, and hence these three groups of the vertebrates are often called

collectively the Amniota; in distinction from them the fishes and amphibians are called the Anamnia. As the young of the Amniota do not develop in the water, gills would of course be useless, although here is evidence of gill slits; so another organ of respiration is necessary for the embryo, and this is found in a sort of membranous sac called the allantois, which develops at the posterior end of the alimentary canal. The yolk supplies nutriment to the young animal and is absorbed through a small region in the ventral body wall called the umbilicus.

The turtles are most abundant in the temperate regions, while other reptiles are most numerous in the tropics, and some, such as the crocodiles and their allies, are essentially tropical in habitat. The reptiles through their fossil representatives show very close relationships to the birds through the fossils of the latter; so that zoologists frequently divide the Vertebrata into three groups: the Ichthiopsida (Gr. *ἰχθύς*, fish, and *ὄψις*, appearance), including the fishes and amphibians; the Sauropsida (Gr. *σαῦρος*, lizard, and *ὄψις*, appearance), including the reptiles and the birds; and the Mammalia. The extinct reptiles are extremely interesting; they were very abundant at one time in the water, on the land, and even in the air, for some were provided with large, membranous wings, much like the bats' (Fig. 318). Some that wandered about on the shore and over the land were veritable giants; the well-preserved skeleton of the Iguanodon (Fig. 319) is nearly ten meters in length, and other fossil reptiles could not have been less than twenty-five to thirty meters long, judging from such of their bones as remain to us. The living Reptilia may be divided into four orders.

### Order 1. Squamata

The Squamata (Lat. *squama*, scale) consist of the lizards and snakes, which have often been regarded as distinct orders, but at present they are generally grouped together. They are reptiles having the body covered with horny scales, which develop from the epidermis or outer layer of the skin, and often bony plates from the derma or deeper layer of the integument as well. The outer horny layer of the skin is cast off periodically in all the Squamata, in most of the serpents

and some of the lizards in one continuous sheet, in the rest in fragments. Appendages, when present, always have the form of legs adapted to walking on land in the living representatives of the group. The cloacal opening is a transverse slit, and there are two copulatory organs, or penes. The lizards and snakes are placed in two suborders.

### Suborder 1. Lacertilia

The Lacertilia (Lat. *lacerta*, lizard) or lizards, usually have two pairs of appendages (Fig. 320), but sometimes the anterior pair is absent, sometimes the posterior, and sometimes both (Fig. 321). But even when the legs are absent, the pectoral and pelvic girdles

FIG. 320. *Lacerta viridis*, the green lizard of Europe. (After Brehm, from Parker and Haswell's Text-book.)

are present; and, further, some of the ribs, which are numerous, meet on the midventral line and fuse to form a breastbone, or sternum. There are usually movable eyelids and a tympanic membrane to the ear, and these structures, together with the skeletal characteristics just referred to, will serve to distinguish the lizards from the serpents. The jaws are capable of but little distention, and the ventral side of the body as well as the

dorsal is usually covered with small scales; in these two points also, we shall see that the lizards differ from the snakes. They are mostly oviparous, the ova being inclosed in a parchment-like shell, but some are viviparous. The shape of the tongue

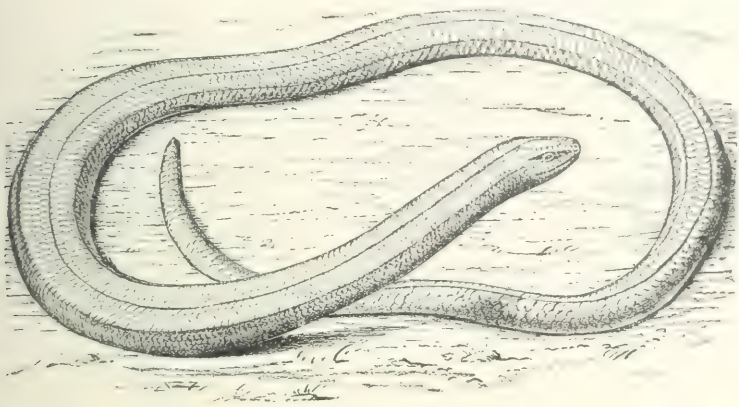

FIG. 321. *Anguis fragilis*, a legless lizard, the blindworm, slightly reduced. (After Shipley and MacBride.)

varies greatly, and this is made the basis of the further subdivisions of the group. In some species it is short, thick, and not protrusible, in others it is vermiform, greatly elongated, and protrusible, and in some it is bifid and slender as in the serpents. The majority feed upon insects, worms, and other small animals, while some are entirely vegetarian in their diet. Some are capable of producing sounds. The tail is usually very fragile and when lost can be regenerated; some species have been known to bite off their own tails.

Lizards are most abundant in the tropics, but they are also numerous in many temperate countries; they vary in size from a few centimeters in length to two meters or more. Many of the larger species are used as articles of food. Although many are very repulsive in appearance, they are for the most part perfectly harmless animals, and in fact the bite of only one species is known to be poisonous. The geckos (Fig. 322) and their allies have curious adhesive discs on their feet, so that they can run up the side of a smooth wall or tree; some of them have folds of skin along the sides of the body, which they open out

as they spring from one object to another, and these act as a parachute to sustain them in the air, — they are known as flying geckos. There are other lizards with similar structures, such as the flying dragons of the East Indies, which are about twenty centimeters in length. Australia is the home of many curious species, such as the frilled lizard, which has a broad frill or collar about its neck and attains a length of nearly a meter; and the moloch, *Moloch horridus*, said to be perfectly harmless, but having the whole body covered with long, conical spines.

FIG. 322. *Platydactylus mauritanicus*, a gecko lizard. (After Claus and Sedgwick.)

The iguana of the warmer portions of America, a vegetarian, is much sought after as an article of food; it is one of the larger lizards, being over a meter and a half in length. A pretty little lizard in our Southern states is called the American chameleon, of the genus Anolis. It has a short body, rarely over nine centimeters long, but a much longer tail, and is of considerable importance because of the large number of insects injurious to vegetation which it eats. It can change its color from a bright green to bronze. Cats are said to be extremely fond of it. Another of our lizards, which is pretty generally known, is the horned toad, — not a toad at all, — which is found west of the Mississippi and from Mexico to British America; there are many species, all perfectly harmless, although repulsive in appearance; they are all viviparous. The glass-snake found east of the Mississippi and south of the Ohio is a legless lizard, which has received its popular name from the readiness with which its tail breaks off. The only poisonous lizard known is found in New Mexico and Arizona and regions southward; it belongs to the genus Heloderma and is the largest North American lizard, being about forty centimeters long. The color is black with irregular orange spots.

The true chameleons live in Africa and some adjoining countries and belong to the genus Chamæleo. They have a very long, vermiform tongue, and are best known because of their ability to

change their color, although other genera of lizards can do this to some extent also. They have two layers of pigment cells in the skin; the more superficial is yellow, the deeper dark brown, and the one or the other can become the more prominent according to the will of the animal.

Although most lizards live on the ground or in trees, some prefer the water, either fresh or salt. They swim mostly by the movement of their tails. Many are used for food, being often over a meter in length, while they themselves are in some cases herbivorous, in others carnivorous, often feeding on crocodile eggs. They are most abundant in Africa, Asia, and Australia. The monitor of the Nile, a lizard two meters in length, is very useful in destroying the eggs of the crocodile.

### Suborder 2. Ophidia

The Ophidia (Gr. *ὄφις*, serpent) consist of the snakes, or serpents. They are elongated reptiles, with a more or less cylindrical body covered with scales, which on the head are so regularly and characteristically arranged as to be of systematic importance. On the dorsal and lateral portions of the body the scales are small; on the ventral side they are usually rather broad plates extending completely across the ventral surface, and thus forming a single series anterior to the cloacal opening; posterior to this opening there are two rows. These ventral scales are called the abdominal scutes, and to them the ventral ends of the ribs are attached. Appendages are absent in the snakes; only in a few species are there rudimentary pelvic limbs in the form of a pair of spinelike projections near the cloacal opening. A pectoral girdle and sternum are always absent, characteristics which distinguish the serpents from the legless lizards.

There is no tympanic membrane, so that the ear is very rudimentary and the sense of hearing dull. They probably notice the jar of an approaching animal. The senses of smell and touch are, however, acute. There are no eyelids, as we have already noted, but a transparent skin in front of the eyes. In nearly all the snakes the bones of the mouth are not united with one another immovably, but are connected by elastic liga-

ments, so that the mouth is very distensible, and they can consequently swallow relatively large animals, although their powers in this direction have been greatly exaggerated in popular narrative. The tongue is slender, bifid, and protrusible, and when retracted lies in a sheath on the floor of the mouth; owing to little grooves in the jaws, the tongue can be thrust out even when the mouth is closed. The teeth are sharp and recurved so that they serve for holding the prey while it is being swallowed; they are not permanent, but may be renewed when necessary; in the poisonous serpents the poison fangs are either grooved or tubular, thus affording a channel for the poison. All serpents feed on living animals, which they swallow whole and then slowly digest; during this time they are very sluggish and inactive. Some also feed upon eggs.

As might be expected from the greatly elongated body, the number of vertebræ is very great; there may be over four hundred, and the ribs are also numerous, there being a pair to each abdominal scute. The motion of the body is produced by the lateral bending of the vertebral column and the movement of the ribs; the scutes press against any roughness on the surface over which the animal is moving and thus produce the locomotion of the body; a serpent cannot move forward upon a perfectly smooth surface. Most of the Ophidia are oviparous, but some bring forth their young alive. Many are brilliantly colored; and often they have a protective coloration, — that is to say, they closely resemble the colors of the objects amongst which they habitually live. They are mostly tropical, although many occur in temperate regions. In their habits they vary considerably; some live underground, buried in the earth or sand; some live among rocks or in deserts; some are arboreal and others aquatic, remaining a part or all of the time in the water, either salt or fresh. They cast the outer, horny layer of their skin periodically, and during some season of the year remain quiescent, taking no food; in the tropical countries this is the hottest season, and in the temperate regions the winter. Serpents are capable of domestication to some extent, and even poisonous species can often be handled with impunity by those accustomed to them. In many species instances have been observed of snakes taking an interest in their mates; when one

has been killed the other will often appear and remain beside its dead companion for a long time. To many people they are the most repulsive of animals, and many species are certainly the most venomous.

A convenient popular classification of the serpents, which is also justified to some extent scientifically, is into the non-poisonous and the poisonous. We may note a few of each kind. Among the non-poisonous snakes are a few small species, from a few centimeters to half a meter in length, which live underground and resemble to a considerable extent the legless lizards. Like them the jaws are not distensible and the eyes are small. On the other hand, some of the largest tropical serpents are not poisonous, but rely on their great strength to kill their prey by crushing it. Among these are the pythons, or rock snakes, which belong to the eastern hemisphere, particularly to the tropical regions of Africa, Asia, and Australia. The stories of these serpents are more wonderful than the animals themselves. In size, the largest actually measured is said to have been a little over six meters long, and from three to four meters is considered a good-sized python. Their food consists chiefly of birds and small quadrupeds, which they capture when they come to the pools to drink, where the python lies in wait. The largest animal which they can swallow is about the size of a small dog. These serpents possess rudimentary hind legs. After laying her eggs the female python coils herself over them and thus protects them during incubation. The royal rock snake of western Africa, *Python regia*, is frequently seen in menageries.

Corresponding in size to the pythons are the boas, which are distinctly American serpents. The emperor snake, *Boa imperator*, of Central America and Mexico is brownish in color and closely resembles the more familiar *Boa constrictor* of Brazil. Related to the boas is the anaconda, also a tropical American snake. Of the smaller non-poisonous snakes many have a bad reputation because of their repulsive appearance. The puffing adder or sand viper, *Heterodon platyrhinos*, a large and ugly-looking snake found east of the Mississippi, is perfectly harmless. The common black snake, which attains a length of a meter or more, is found all over the United States from the Atlantic to the Pacific; it often lives near the water and rolled

up on the tops of bushes. Though having no poison gland, its sharp teeth can inflict an unpleasant bite, and it is strong enough to strangle young children, although it rarely attacks human beings. The indigo or gopher snake, *Spilotes couperi*, which reaches a length of three meters, is found in some of our Southern states and is never molested by the negroes, as they consider it a natural enemy of the rattlesnake. The garter snakes of the eastern United States are harmless, but emit a most disagreeable odor when captured. Many non-poisonous snakes, it should be said, strike at the eyes of passers-by and are dangerous on that account.

The poisonous serpents are generally considered under two heads, those in which the poison fangs are fixed rigidly in position, and those whose fangs can be erected or depressed at will. In the first of these groups belong the most deadly serpents. The best-known and the commonest, as well as one of the largest, is the dreaded cobra-da-capella of India, *Naja tripudians*. Thousands of natives die from its bite every year. Like several of its relatives, it possesses the power of expanding its neck laterally, on the back of which are the curious markings resembling a pair of spectacles; they exhibit great variation in color and markings and are favorites with the Indian serpent charmers. Related to the cobra is the asp of northern Africa, *Naja haje*, which Cleopatra has rendered classical. But there is a larger and more deadly serpent than the cobra: it belongs to the genus Ophiophagus and is the most venomous animal in existence; its poison is said to kill a man in three minutes and an elephant in two hours. It reaches a length of four and a half meters. Fortunately it is rare; it inhabits India, Java, and some adjacent islands, and feeds chiefly on other serpents. Of the smaller poisonous snakes with fixed fangs some of the most widely distributed and best known are the harlequin snakes, found in America, the East Indies, South and North America. They have the body marked by circular bands of black, red, or yellow. Australia is very abundantly supplied with poisonous serpents. There are many poisonous sea snakes, particularly in the Indian and Pacific oceans. They appear blinded and helpless when taken from the water and soon die; the tail is laterally compressed and so serves for an organ of locomotion in

the water. All are viviparous. Many are small, but one species attains a length of two and a half meters and another three and a half.

Taking now the poisonous serpents in which the fangs are movable, we find that they can eject the poison if they choose without striking the victim with their fangs. The poison is said to be harmless when taken into the alimentary canal, and hence, when bitten, it is customary to suck the wound at once, taking every precaution to keep the poison out of the circulation by a ligature; alcoholic stimulants are valuable in keeping up the heart's action. All these serpents bring forth their young alive.

Of the vipers the most dangerous is the horned viper of Africa, although it is not so deadly as the cobra. In Europe there is only one poisonous snake, the asp, called *Vipera aspis*, which extends as far north as Sweden; it inflicts a very painful bite, but rarely fatal. In England there is also only one poisonous snake, the adder, *Pelias verus*. In South Africa the largest and most poisonous snake is the puff adder, over a meter in length; its poison is used by the natives to poison their arrow points. On the American continent the representatives of this group have stout bodies with triangular, flattened heads, rather sharply marked off from the rest of the animal by a narrower neck. Aside from the rattlesnakes the most dangerous in the United States are two, the copperhead, *Ancistrodon contortrix*, found in mountain districts from New England to Florida and from the Atlantic to the Mississippi; it derives its name from the bronze-colored head; the body is reddish brown with darker bands; and the water moccasin, *Ancistrodon piscivorus* of our Southern states from the Carolinas to Texas; it lives in or near the water, is only a little over a meter long, an olive color with black bars above and lighter below; it is much dreaded.

The most deadly serpent in the western hemisphere is the fer-de-lance of Brazil, which causes the death of many persons yearly. There are a number of small snakes, popularly called rattlers because of a small rattle, such as the black rattlesnake of our Central states, which lives in the burrows of the prairie dogs, the ground rattlesnakes of the South, and others in

Mexico; but the true rattlers belong to the genus Crotalus (Fig. 323), of which we have about fifteen species. The rattles at the tip of the tail are merely remains of the cast-off skin, and as they break off readily they give no indication of the age of the snake, as popular belief asserts. The western black rattlesnake, *Crotalus lucifer*, is most abundant south of the Columbia River. In the southern United States we have the diamond or water rattler, *Crotalus adamanteus*, often found in damp places. East of the Mississippi the most abundant is *Crotalus horridus*, the banded rattlesnake, about a meter long, and ranging from Maine to Texas. It feeds upon small rabbits, rats, and squirrels. In California, Arizona, and Mexico is found in desert regions the curious horned rattler, *Crotalus cerastes*, which resembles the horned viper of Africa. In Arizona also is the species *Crotalus pyrrhus*, noteworthy because of its brilliant red color. The story that serpents charm their prey by fixedly gazing at it is now relegated to the collection of other zoölogical fables; the apparent inability of the prey to flee, is probably due to an excessive fright, which practically paralyzes the animal.

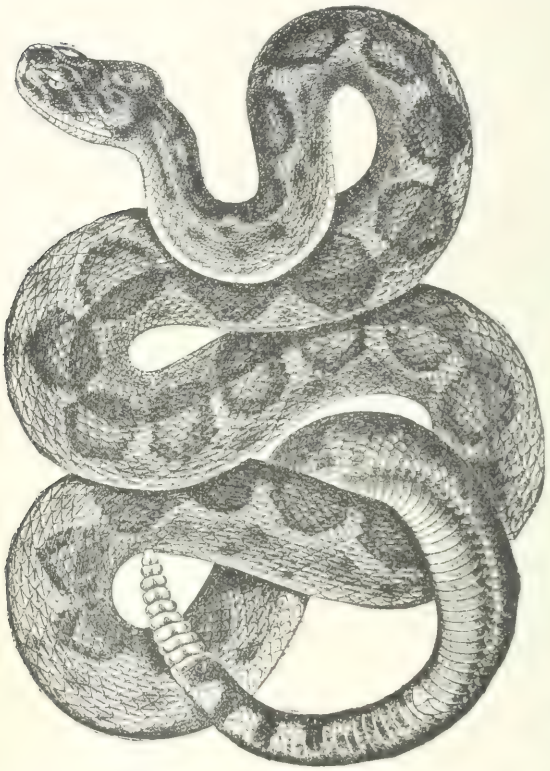

FIG. 323. *Crotalus atrox*, the Texas rattlesnake; reduced. (After Baird and Girard, from Shipley and MacBride's Zoölogy.)

### Order 2. Rhynchocephalia

The Rhynchocephalia (Gr. *ῥύγχος*, snout, and *κεφαλή*, head) are represented by a single animal, *Hatteria* (or *Sphenodon*) *punctata* (Fig. 324), found in New Zealand. It is lizard-like in appearance, green with yellow spots above and whitish below, and about half a meter in length. The tail is long, the body

FIG. 324. *Hatteria punctata*. (After Brehm, from Parker and Haswell's Manual.)

scaly, the cloacal opening a transverse slit, and there are no copulatory organs. The legs are pentadactyl and adapted to walking. It is an important animal because of its fossil relations. As it is largely eaten by natives it will doubtless soon become extinct itself.

### Order 3. Chelonia

The Chelonia (Gr. *χελώνη*, turtle), consisting of the turtles and tortoises as they are popularly called, form a group sharply marked off from the other reptiles. The two common names are now applied to any member of the order; at one time the term *turtle* seems to have been restricted to the marine species. While in all the other orders the body is elongated, here it is short and stout, and is provided with upper and lower shields (Fig. 325); these consist in part of flattened portions of the vertebral column and ribs, and in part of dermal bones. The dorsal shield is called the carapace, the ventral the plastron, and they are generally covered with the horny epidermis, which in some of the larger turtles is called tortoise shell. The head

with its long neck, the four legs, and the tail can generally be drawn under the edge of the carapace so as to be scarcely visible; they are covered with a scaly epidermis, resembling that in the Squamata.

The appendages may have the digits distinct and terminating in bony claws, or they may have membranes between them, or they may all be inclosed in the integument so that the appendage becomes a paddle-like structure or flipper instead of a foot. On the head are the tympanic membranes; the eyes are provided with eyelids; the jaws are entirely without teeth, but have very sharp cutting edges consisting of the hard, horny epidermis;

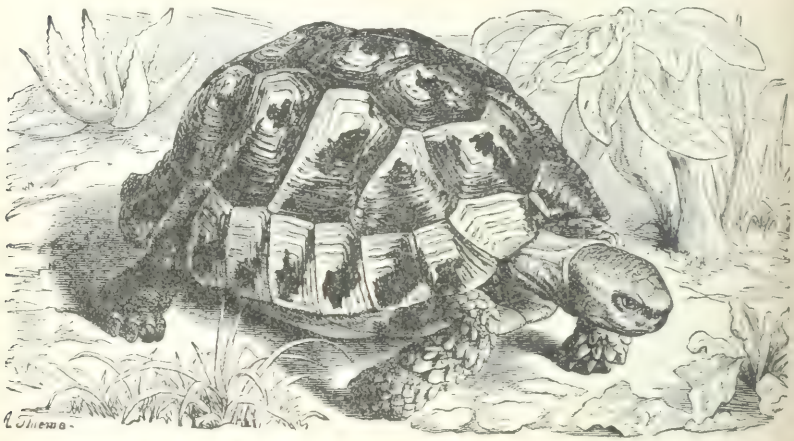

FIG. 325. *Testudo graeca*, Greek tortoise. (After Brehm, from Parker and Haswell's Manual.)

the tongue is attached to the floor of the mouth, and is not protrusible. The cloacal opening is at the root of the tail and is circular or longitudinal, not transverse, as in the preceding orders. There is a large urinary bladder on the ventral side of the cloaca, and in the male the copulatory organ consists of a median penis attached to the ventral cloacal wall; a corresponding organ, less developed and known as the clitoris, occurs in the female in a similar position. The turtles are all oviparous, depositing their eggs, inclosed in leathery or calcareous shells, in the sand or earth, where they are left to incubate.

Some Chelonia feed entirely on plants, others on animals such as fish and various invertebrates. They are essentially tropical,

but extend into temperate zones as well; the land tortoises sleep during the dry season in hot countries, in cold countries turtles hibernate like the snakes and amphibians. These animals grow slowly, and live to a great age unless killed by violence; many attain sexual maturity only after a number of years, and one female is reported to have laid eggs for the first time when eleven years of age.

The largest turtles are marine. The largest of all is the leather back, which attains a length of nearly two meters, and a weight of seven hundred and fifty kilos. Its appendages are paddle-like. Instead of a horny epidermis, it has a thick, leather-like skin. Its eggs have a diameter of four centimeters and are considered very palatable; the flesh is said to be less so. There is only a single representative of this kind of turtle, one genus and one species, but it is widely distributed, living in the Atlantic, Pacific, and Indian oceans and in the Mediterranean. The hawkbill turtles are small marine Chelonia, one species occurring on the eastern coast of the United States; the old individuals contribute a good quality of tortoise shell. The flesh of the hawkbills, as well as of the much larger American loggerhead, is inferior as food, but the eggs are very good and much sought after. The best marine turtle for food is the green turtle, *Chelonia midas*, found along the American coast from southern Brazil to Cape Hatteras; they are vegetarians, and may attain a weight of four hundred and twenty-five kilos. The females crawl up on the sandy beaches at night and make a hollow excavation, in which they deposit their eggs and then cover them with sand; as they return to the same place several times at intervals of about two weeks to deposit eggs, the fishermen discover them by their tracks, and, lying in wait, when they appear, turn them on their backs, and later drag them away at their leisure, for these large turtles when on their backs on land cannot turn over.

There is a fresh-water turtle whose shell is nearly circular and about half a meter in diameter, called the soft-shelled turtle; its flesh is much sought after, as it is said to be superior even to that of the green turtle. All the so-called fresh-water turtles of the globe have been classed in the family Emydidæ; the toes may be distinct or webbed, according as they are most

in the habit of walking or swimming. In all of these the shell is covered with horny scales. One of the best known in the United States is the painted turtle, *Chrysemys picta*, which is found from the Gulf of Mexico to the Gulf of St. Lawrence. It is dark brown above, with the scales bordered with yellow, and the marginal plates marked with concentric red lines; the plastron is yellow. Another species of this genus is found in the West. North and east of the Ohio the speckled turtle, *Chelopus guttatus*, is very abundant; the carapace is black with small yellow dots, which increase in number with age. To the epicurean the most familiar turtle is the diamond-back terrapin, *Malaclemmys palustris*. It lives in marshes along the Atlantic coast from New York to Texas and even farther south. The adult male has the carapace about fifteen centimeters long; the female, which is considered the more valuable because of the eggs she contains, may be two or three centimeters longer. They are very abundant about Charleston, and the two sexes are known respectively as bulls and cows in the market. They are rapidly diminishing in numbers owing to the enormous quantities captured yearly and their slow rate of growth. The snapping turtle, *Chelydra serpentina*, is found in America from Canada to Equador, and may attain a length of about a meter. It lives in the water or on land and is one of the fiercest reptiles found in the United States. The genus Testudo includes turtles which are strictly land animals; one of the most familiar in the United States is the gopher turtle, whose shell is often about forty-five centimeters in length. A giant fossil tortoise of India is worthy of mention because of its great size; it was six meters in length, and the carapace was nearly two and a half meters high.

### Order 4. Crocodilia

The Crocodilia (Gr. κροκόδειλος, crocodile) are represented in all tropical countries of the world, and in their internal structure are the most highly developed of the Reptilia. They have an elongated body with four well-developed legs and often claws on the digits. The tail is laterally compressed so as to serve as an organ for swimming. The body is covered with a thick,

leathery skin, with bony dermal scutes on the dorsal side and sometimes on the ventral as well, covered with horny epidermal scales. The eyes are provided with eyelids, and the ears and nostrils are supplied with valves which can be closed when the animal is under water. The jawbones are provided with numerous conical teeth, which are firmly set in sockets in the bone. The tongue is thick, attached to the floor of the mouth, and not protrusible. At the back of the mouth is a structure which prevents the water from entering the lungs if the animal has its mouth open under water. The cloacal opening is a longitudinal slit, and on the ventral wall of the cloaca is an erectile, median copulatory organ or penis. Near the cloacal opening is a pair of apertures which connect the body-cavity directly with the outside; they are called the peritoneal canals or the abdominal pores and are found in turtles also; their function is unknown, but they recall the abdominal pores of some fishes, though the structures are probably not homologous in the two groups. The Crocodilia are among the largest existing reptiles and are exclusively tropical, living in the mouths and lagoons of large rivers all around the world; they seek their prey at night. They include the gavials, crocodiles, alligators, and caimans.

FIG. 326. *Gavialis gangeticus;* head of a gavial. (From Ludwig-Leunis' Synopsis der Thierkunde.)

The gavial of India (Fig. 326) is one of the largest of this order; it sometimes reaches a length of six meters. It may readily be distinguished from the other Crocodilia by the narrow, elongated snout with its slightly swollen tip. The crocodiles (Fig. 327) belong to the genus Crocodilus and are found all over the world. They extend over the whole continent of Africa; the crocodile of the Nile was sometimes embalmed by the ancient Egyptians. In India the

FIG. 327. *Crocodilus vulgaris;* head of the crocodile of the Nile. (From Ludwig-Leunis' Synopsis der Thierkunde.)

crocodile lives only in salt-water estuaries, but is found among the East Indies and in Australia, the West Indies, Central America, and in Florida. The crocodiles may be distinguished by the breadth of the snout, which is intermediate between that of the gavials and the alligators. The alligator, *Alligator mississippiensis* (or *lucius*) (Fig. 328) is found only in America and was once very abundant in our Southern states; it is fast disappearing, owing to the extent to which it is hunted. It feeds on fishes and the smaller mammals, such as the muskrat; it is said to be particularly fond of dogs. It kills its prey by drowning it,—keeping it below the surface of water,—and does not drown itself because of the structure at the back of the mouth already referred to. The caiman closely resembles the alligator and is found in the Orinoco. The eggs of the alligator, about the size of a hen's egg, are provided with a hard shell; they are laid in sandy mounds, which the animals sometimes construct for themselves on the banks of streams. When the young hatch, they at once seek the water.

FIG. 328. *Alligator mississippiensis;* head of the American alligator. (Slightly altered from Ludwig-Leunis' Synopsis der Thierkunde.)

## CLASS V. AVES

The Aves (Lat. *avis*, bird), or birds, are sharply marked off from all the other vertebrates by the fact that the body is more or less completely covered with feathers; these structures occur in no other group of animals. They are, further, the first warm-blooded animals that we have considered, for the temperature of the blood is kept pretty constantly at about 38° Centigrade, despite variations in the temperature of the bird's environment. The general shape of the body is oval with a movable neck, generally relatively long and surmounted by a light head with a projecting beak. In most birds the body terminates posteriorly in a tail provided with stiff feathers, which serve as a steering apparatus in birds that fly. The anterior appendages have the form of wings, which are folded back against the sides of the

trunk when not in use. The body when the bird is running on land or standing is supported entirely by the two posterior appendages, which terminate as a rule in four toes tipped with claws (Fig. 329).

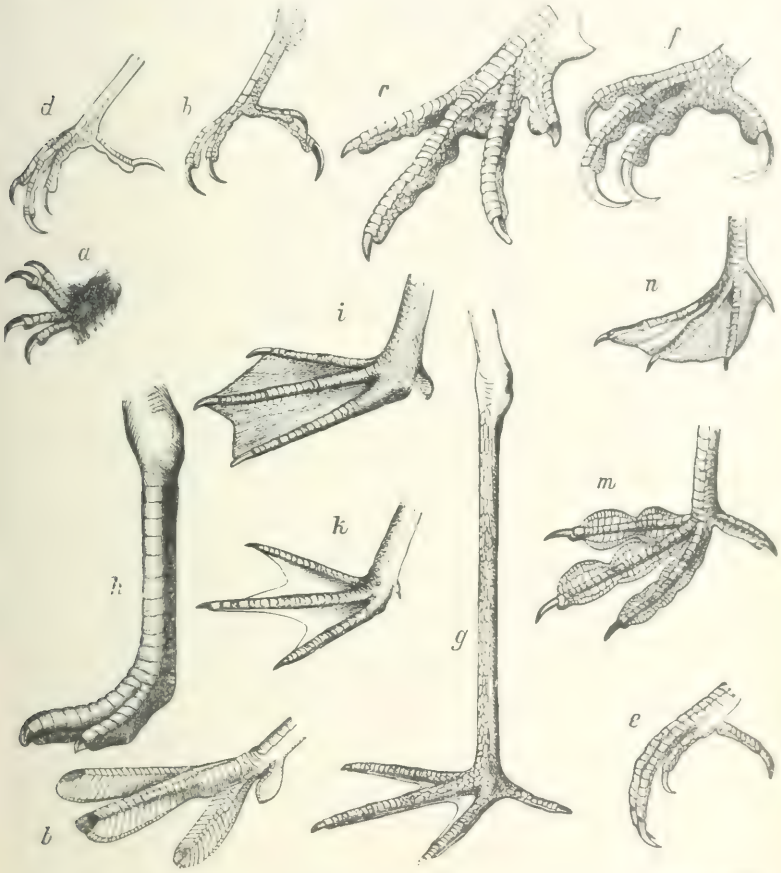


FIG. 329. Various forms of birds' feet. *a*, *Cypselus apus*, pes adhamans; *b*, *I*[illegible] pes scansorius; *c*, *Phasianus colchicus*, pes ambulatorius; *d*, *Turdus torquatus*, pe[illegible] *e*, *Alcedo ispida*, pes gressorius: *f*, *Falco biarmicus*, pes insidens; *g*, *M*[illegible] pes colligatus; *h*, *Struthio camelus*, pes cursorius; *i*, *Mergus me*[illegible] pes palmatus; *k*, *Recurvirostra avocetta*, pes semi-palmatus; *l*, *Podiceps cristatus*, [illegible] palmatus; *m*, *Fulica atra*, pes lobatus; *n*, *Phaëton æthereus*, pes steganus. (From Claus and S[illegible] wick's Text-book.)

There are several kinds of feathers found on birds, the two most important being the stiff contour feathers which give the general shape to the body, and the softer plume- or down-

feathers beneath. The contour feathers are not generally distributed evenly over the whole body, but are attached only on certain areas called the feather tracts (Fig. 330). Some of the larger feathers have special names, particularly on the wings and tail. Thus the largest feathers on the wing are known as remiges, and these are divided into three groups: those attached to the hand are the primaries, those on the forearm are the secondaries, and the three secondaries nearest the body are called the tertiaries. The primaries are usually ten in number; the secondaries are variable. Further, the remiges are overlaid

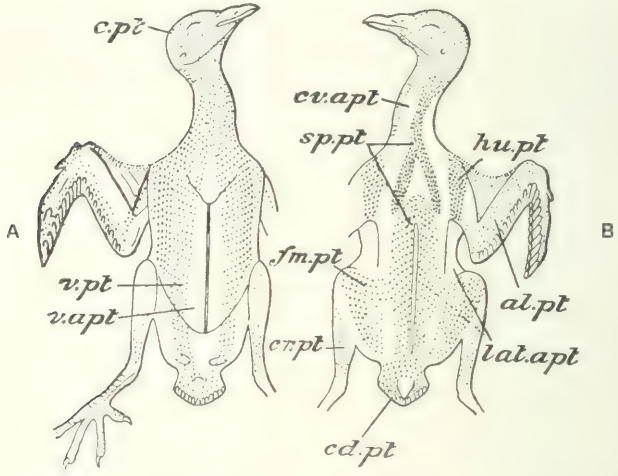


FIG. 330. *Columba livia*, the pigeon; pterylosis. A, ventral aspect; B, dorsal. *al.pt*, alar pteryla or wing tract; *c.pt*, cephalic pteryla or head tract; *cd.pt*, caudal pteryla or tail tract; *cr.pt*, crural pteryla; *cv.apt*, cervical apterium or neck space; *fm.pt*, femoral pteryla; *hu.pt*, humeral pteryla; *lat.apt*, lateral apterium, *sp.pt*, spinal pteryla; *v.apt*, ventral apterium; *v.pt*, ventral pteryla. (After Nitsche, from Parker and Haswell's Manual.)

both above and below at their attached ends by smaller feathers which are called respectively the upper and under wing coverts (Fig. 331). The largest feathers of the tail are called rectrices, as they are used in steering in the flying birds. They are also provided with coverts, which sometimes are very highly developed, as in the tail of the peacock.

The skin of birds is destitute of glands except for one found on the dorsal side of the base of the tail; it is an oil gland, called the uropygial gland, and its secretion serves to oil the feathers. Other epidermal structures, besides the feathers,

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which are found in birds are the horny epidermal scales, which are very common on the legs and feet; bony plates, or scutes, never occur. In some male birds there are also spurs on the legs; these are likewise horny structures. Both upper and

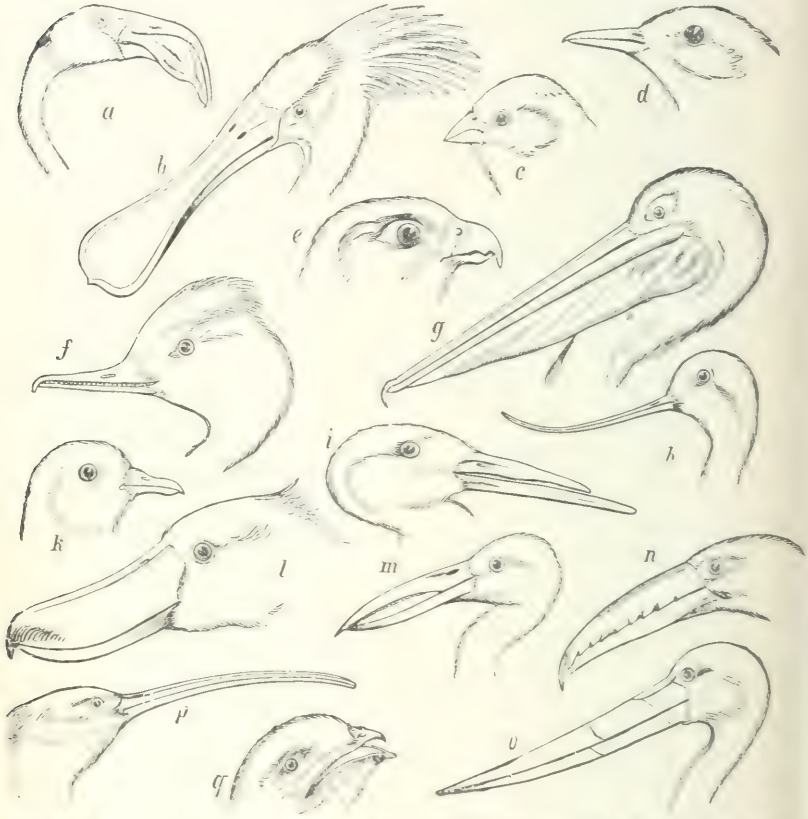



FIG. 332. Various forms of beaks. *a*, *Phoenicopterus ruber*; *b*, *Platalea leucorodia*; *c*, *Emberiza citrinella*; *d*, *Turdus cyanus*; *e*, *Falco candicans*; *f*, *Mergus* [illegible]; *g* [illegible]; *h* [illegible]; *i* [illegible]; *k* [illegible]; *l* [illegible]; *m* [illegible]; *n* [illegible]; *o* [illegible]; *p* [illegible]; *q* [illegible]. (From Claus and Sedgwick's Text-book.)

lower jaws are inclosed in a hard, horny sheath constituting the beak (Fig. 332), at the root of which is a mass of naked skin, called the cere, and near this in the upper beak lie the external nasal openings; the organ of smell is poorly developed in birds. The eyes are provided with eyelids, and are capable

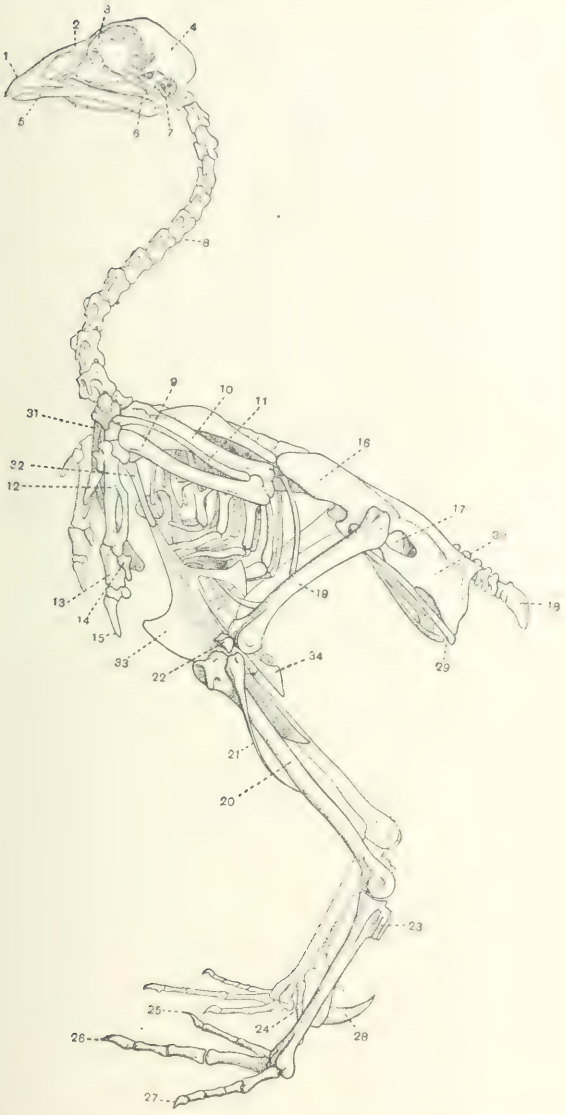



Fig. 333. *Gallus bankiva*, the common fowl, ♂. Skeleton reduced one half. 1, premaxilla; 2, nasal; 3, lachrymal; 4, frontal; 5, mandible; 6, lower temporal arcade of [illegible] of quadrato-jugal; 7, tympanic cavity; 8, cervical vertebrae; 9, scapula; 10, humerus; 11, radius; 12, carpo-metacarpus; 13, first phalanx of second digit; 14, third digit; 15, [illegible] digit; 16, ilium; 17, ilio-ischiatic foramen; 18, pygostyle; 19, femur; 20, tibio-tarsus; 21, fibula; 22, patella; 23, tarso-metatarsus; 24, first toe; 25, second toe; 26, third toe; 27, fourth toe; 28, spur; 29, pubis; 30, ischium; 31, clavicle; 32, coracoid; 33, sternum; 34, xiphoid process. The forked bone just in front of 7 is the quadrifurcate. (After Shipley and MacBride.)

of accommodating themselves to objects at very varied distances. Farther back on the head are the external auditory openings, often surrounded by a special row of stiff feathers. This opening leads into a short tube called the external auditory meatus, at the deeper end of which is the tympanic membrane; within this is the tympanic cavity, which connects with the mouth by means of the Eustachian tube.

There are over twelve thousand known species of living birds distributed over the whole world, and many of great economic importance to man, not only as destroyers of insects and other undesirable animals, but also as an article of food; so we may give a brief account of the structure of a typical bird, beginning with the skeletal system (Fig. 333). In most birds the bones are extremely light, since they contain air chambers. The skull is remarkably so, and there is great fusion of the various bones which compose it. The vertebræ of the neck are very movable, and vary in number from nine to twenty-three, the maximum number being found in the swan, which has more cervical or neck vertebræ than any other animal. The neck is succeeded by the thoracic portion of the vertebral column, which is rigid and bears the ribs, which join the sternum or breastbone on the ventral side of the body; the sternum bears a projection or keel on its median line in all birds which use the wings for flight. Posterior to the thoracic vertebræ is the pelvis, a large, bony mass consisting of many fused vertebræ, and this is succeeded by a few caudal or tail vertebræ; some extinct birds were provided with a very long tail, but it is short in all living species. The bones of the wing are attached to the pectoral girdle, of which the most familiar bone is the wishbone, or merrythought as it is called in England; it is known technically as the furcula, and corresponds to the collar bone in mammals. In the wing we distinguish the same parts as in the human arm, the upper arm, forearm, and hand. The skeleton of the posterior appendage is attached to the pelvis, and in it again we distinguish the same parts as in man, thigh, leg, and foot. The shape of the foot varies with the use to which it is put, such as swimming, scratching, running, or grasping.

Concerning the internal organs (Fig. 334), we note the brain is more highly developed than in any of the vertebrates that we

have considered thus far; from it passes off the spinal cord, which lies in the neural canal of the vertebral column, and sends off a pair of nerves for each vertebra, which go to the various parts of the body. The muscles are attached to the bones, and serve

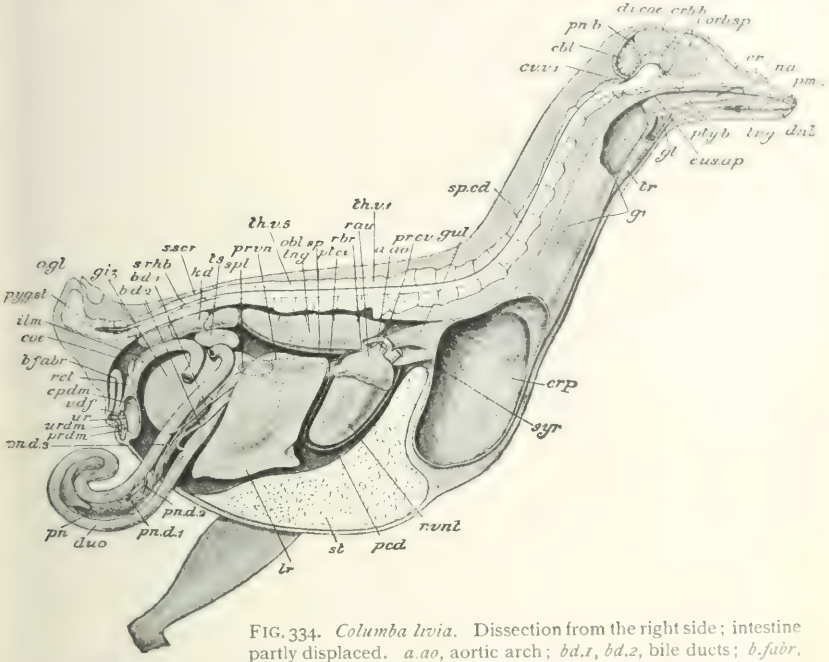



FIG. 334. *Columba livia.* Dissection from the right side; intestine partly displaced. *a.ao*, aortic arch; *bd.1*, *bd.2*, bile ducts; *b.fabr*, bursa fabricii; *cbl*, cerebellum; *coe*, right cœcum; *cpdm*, coprodæum; *cr*, cere; *crb.h*, left cerebral hemisphere; *crp*, crop, cut open; *cv.v.1*, first cervical vertebra; *d1.coe*, diacœle; *dnt*, dentary; *duo*, duodenum; *eus.ap*, aperture of Eustachian tube; *giz*, gizzard, dotted behind the liver; *gl*, glottis; *gul*, gullet, in part cut open; *ilm*, ilium; *i.orb.sp*, interorbital septum; *kd*, right kidney; *lng*, right lung; *lr*, liver, right lobe; *na*, bristle passed from nostril into mouth; *obl.sep*, oblique septum; *o.gl*, oil gland; *pcd*, pericardium; *pm.x*, premaxilla; *pn*, pancreas; *pn.b*, pineal body; *pn.d.1–3*, pancreatic ducts; *pr.cv*, right precaval; *prdm*, proctodæum; *prvn*, proventriculus, dotted behind the liver; *pt.cv*, postcaval; *pty.b*, pituitary body; *pyg.st*, pygostyle; *r.au*, right auricle; *r.br*, right bronchus; *rct*, rectum; *r.vnt*, right ventricle; *sp.cd*, spinal cord; *spl*, spleen, dotted behind the liver; *s.rhb*, sinus rhomboidalis; *s.scr*, syn-sacrum; *st*, carina sterni; *syr*, syrinx; *th.v.1*, first thoracic vertebra; *th.v.5*, fifth thoracic vertebræ; *tng*, tongue; *tr*, trachea; *ts*, right testis; *ur*, aperture of left ureter; *urdm*, urodæum; *v.df*, aperture of left vas deferens. (After Parker and Haswell.)

to move them; the largest are the muscles of the thigh and leg, and the muscles of the breast; the latter are the large pectoral muscles attached to the keel of the sternum, and serve to move the wings in flight.

The digestive system begins at the mouth, which is entirely

without teeth in all living birds, although some extinct birds had a good supply of them. The tongue is well developed, conforming in shape to the shape of the beak, and usually has a firm covering. The form and size of the beak vary enormously according to the nature of the bird's food. The œsophagus leads from the mouth to the stomach, and sometimes has a saclike enlargement on its ventral wall, the crop, which serves for the storage of food, and in some cases acts upon it by glandular secretions. The stomach generally consists of two parts: the anterior, glandular stomach, and just posterior to this the muscular stomach, or gizzard, where the food is ground up. From the gizzard a long, coiled intestine passes to the cloaca, which opens on the ventral side of the body at the root of the tail. Opening into the intestine near the stomach is a gland, the pancreas, whose secretion assists in digestion, and the secretion of bile from the liver enters the intestine in the same region. Near the intestine is a small, red body, the spleen, whose function is unknown.

The air passes into the nostrils to the back of the mouth, and then into the windpipe, or trachea, which divides at its posterior end into two bronchi, going to the lungs. The opening into the trachea is called the glottis, and this is succeeded by the larynx, which in other vertebrates is the organ of voice or sound; but in the birds all sound is produced by a second larynx, which lies at the opposite end of the trachea, at the point where it divides into the two bronchi; this second larynx is technically called the syrinx. The lungs are thin-walled sacs which connect with a number of very thin air sacs placed in various parts of the body, and these in turn communicate with the air spaces in the bones already referred to. In some birds there are even air spaces in the skin as well.

The heart is a relatively large, muscular organ, lying dorsal to the sternum, and consists of four chambers, two auricles with thin walls, and two ventricles with thick walls. The blood is collected from the various parts of the body by veins, and passes into the right auricle, from which it goes to the right ventricle, and then to the lungs; after being aërated it flows to the left auricle, thence to the left ventricle, and then into the arteries, which carry it to all parts of the body. The excretory organs

consist of a pair of kidneys lying in the abdominal region, whose ducts, the ureters, open into the cloaca. There is no urinary bladder, and the secretion from the kidneys is not a fluid, but a whitish, semifluid substance.

The reproductive organs in the male are a pair of testes lying within the body-cavity, from which numerous fine tubes pass on into one duct for each testis,—the *vas deferens*, and the two *vasa deferentia* open into the cloaca. There is no copulatory organ, as a rule, although a rudimentary one is found in some birds, and in the ostriches there is a single penis developed on the wall of the cloaca very much like that in the Chelonia and Crocodilia. In the female the right ovary and oviduct are very rudimentary or absent; the left is alone functional and the oviduct consists of several regions. The eggs are fertilized in the anterior portion of the tube, and then as they pass toward the cloaca they are surrounded by the albumen, the shell membranes, and finally by the calcareous shell.

All the birds are oviparous. The number of eggs varies from one to many in different species. Heat is necessary for incubation, and this is generally secured by the bird's sitting on the eggs. In some cases it is the female alone that sits, in some cases the male and female alternate with each other at pretty definite intervals. Most birds are monogamous, and most build nests; usually it is the female only that builds the nest; in some cases the male assists in bringing the material for it, in others he takes no part whatever in the work. The nests are often very elaborate structures, but some are a loosely arranged mass of sticks, a hole in the ground, or a shallow excavation in the sand, as in the case of the ostriches. The habits of the European cuckoo and the American cowbird are well known; they build no nest and do not sit upon their eggs, but deposit them in the nests of other birds, which incubate them and feed the young. The period of incubation varies greatly, from eleven or twelve days in the case of the hummingbirds to seven or eight weeks in the case of the ostriches. In their development an amnion and allantois are formed as in the reptiles. In different species the young are born in very different stages of development. In some, as in the domestic fowl, the young when hatched are covered with down, have their eyes

open, and can run about and feed themselves; such young birds are called *præcoces* or precocious. Others are nearly naked, blind, require long feeding by the mother bird, — the male rarely assists, — and have to be taught to fly. Such young are called *altrices*, or non-precocious. There is usually considerable sexual dimorphism in birds; in most cases the male is larger and stronger than the female, though sometimes smaller, and he is usually more brilliantly colored and has a richer voice. Both the coloration and the song are most brilliant at the breeding season.

Birds are found all over the world. Some live permanently in the tropics, others in the temperate regions. As they never hibernate, they cannot live permanently in excessively cold climates, and so they migrate in the spring from tropical to temperate and even arctic regions, and in the autumn return to warmer countries. The tropical species are by far the most brilliantly and beautifully colored. Fossils are rare in this class, but what we have are of very great importance, since, as we have already noted, they show a close relationship to some fossil reptiles, and so we may infer a reptilian origin for the Aves.

The group, because of the presence of feathers, is very sharply marked off from all other groups of animals; but the further classification of the many thousand species is a matter of the greatest difficulty and one upon which scarcely any two zoologists agree. For a long time birds were divided into two groups, the Ratitæ (Lat. *ratis*, raft) and the Carinatæ (Lat. *carinatis*, keel-shaped), and this classification is even preserved by some zoölogists to-day. In the former group were placed the running birds, such as the ostrich, which have no keel on the sternum, and in the latter all the birds which have a keel. The Carinatæ were then subdivided into a number of groups according to the habits of the species, such as waders, scratchers, swimmers, and birds of prey, a classification almost as unnatural as it would be to place the marine serpents with the fishes because both inhabit the water. Consequently our revised classification rests on the structure and development of the different species, to a considerable extent on the variations in the skull. The following classification will serve as a practical foundation for the student who wishes to make a more detailed study of

FIG. 335. *Dinornis robustus*, one of the moas; skeleton; actual height over two and three quarters meters (nine feet and a half). (After Parker and Haswell.)

this class; the general student can get along very well without it. It may be noted that the groups labeled suborders are considered orders by some zoologists, and by others families merely. The classification does not include the fossil birds.

### SUBCLASS I. DROMÆOGNATHÆ

In the Dromæognathæ (Gr. *δρομαῖος*, fleet, and *γνάθος*, jaw) the wings are rudimentary and the birds are generally incapable of flight.

FIG. 339. *Apteryx australis*, the kiwi, with egg. (After Parker and Haswell.)

### Order 1. Struthiones

The members of the Struthiones (Gr. *στρυθίων*, ostrich) are the largest living birds. They have no keel on the breastbone, and the furcula is not developed. They include the African ostrich, genus Struthio, which has two toes; the South American ostrich, genus Rhea, which has three toes; the cassowaries,

Casuaris; and the emus, Dromaius. Nearly all the bones are heavy and contain marrow instead of air spaces as in flying birds. The extinct, gigantic moas (Fig. 335) of Australia and New Zealand belong to this group; they appear to have become extinct since man lived in those countries. The African

FIG. 337. *Apteryx australis;* skeleton. (After Parker and Haswell.)

ostrich supplies the valuable feathers of commerce, and now ostrich farms are maintained in this country in California. These birds may attain a height of over two meters and a weight of a hundred kilos. The eggs are from twelve to fifteen centimeters long and require seven or eight weeks for incubation.

### Order 2. Apteryges

The Apteryges (Gr. *ἀ*, without, and *πτέρυξ*, wing) consist of a single genus, Apteryx (Figs. 336 and 337), with four species, living in New Zealand. They are the kiwis, small birds about

FIG. 338. *Eudyptes antipodum*, a penguin. (After Buller, from Parker and Haswell's Text-book.)

as large as the domestic fowl, with long beaks, at the tip of which are the nostrils. The body is covered with hairlike feathers. The egg is very large, being about a quarter the weight of the adult bird. There is no furcula or wishbone, and a keel is absent from the sternum.

### Order 3. Crypturi

The Crypturi (Gr. *κρυπτός*, hidden, and *οὐρά*, tail) have a keel on the sternum and the wings are sufficiently well developed to admit of short flights. There are about fifty species living in Central and South America. They are all about the size of the domestic fowl, or smaller; the tinamou, Tinamus, is one of the most common.

## SUBCLASS II. IMPENNES

The Impennes (Lat. *in*, without, and *penna*, wing) are aquatic birds; the wings are paddle-like and used only for swimming; they are commonly called penguins (Fig. 338). In these birds the feathers are uniformly distributed over the whole integument and not confined to special tracts as in most other birds. Beneath the skin is a thick layer of fat, which assists in maintaining the temperature of the body, for the penguins live only in the colder regions of the southern hemisphere, and never on the mainland, but always on rocky and barren islands. They are expert swimmers, feeding on fishes and other marine animals, and when on shore stand erect, side by side, in large "schools." The largest species, the king penguin, is about a meter high.

## SUBCLASS III. EUORINTHES

The Euorinthes (Gr. *εὖ*, well, and *ὄρνις*, bird) include all the remaining birds; they have the wings well developed and adapted to longer or shorter flights. The feathers are arranged on definite feather tracts, and the sternum bears a keel. The following division into orders is based on differences in the arrangement of the bones which form the roof of the mouth, the details of which need not concern us here.

### Order 1. Desmognathæ

(Gr. *δεσμός*, a band, and *γνάθος*, jaw)

#### Suborder 1. Steganopodes

The Steganopodes (Gr. *στεγανόπους*, web-footed) have webbed feet and are good flyers; they include the boatswain birds, the

gannets, the frigate birds, the cormorants, the darters, and the pelicans (Fig. 339). They are widely distributed, occurring all around the globe.

### Suborder 2. Herodii

The Herodii (Gr. ἐρωδιός, heron) are wading birds, with long legs and the feet generally not webbed; they fly well. The

FIG. 338. [illegible] pelicans and young. (From a photograph provided by the American Museum of Natural History.)

group includes the herons (Fig. 340), storks, ibises, spoonbills, and bitterns; some zoologists place the flamingoes here also.

### Suborder 3. Anseres or Chenomorphæ

The Anseres (Lat. *anser*, goose), or Chenomorphæ (Gr. χήν, goose, and μορφή, form), generally have webbed feet and are good swimmers; most of them fly well also, and the young are precocious. They include the many different genera of ducks (Fig. 341), geese, swans, and screamers; and the flamingoes may be placed here instead of in the preceding order. This group is of world-wide distribution.

### Suborder 4. Accipitres

The Accipitres (Lat. *accipiter*, bird of prey) are the diurnal birds of prey, characterized by the hooked beak and the sharp claws or talons on their toes, three of which are directed forward; the feet are not webbed. They feed entirely upon other animals, and are remarkable for their strength and power of

FIG. 340. *Ardea herodias*, the great blue heron. (From a photograph provided by the American Museum of Natural History.)

flight; their sight is extraordinarily keen. The female bird is often larger and stronger than the male. There is great variation in size in this group, the extremes being the small falcons, not over fifteen centimeters in length, and the vultures, with an expanse of wing of over four meters and a weight of ten kilos.

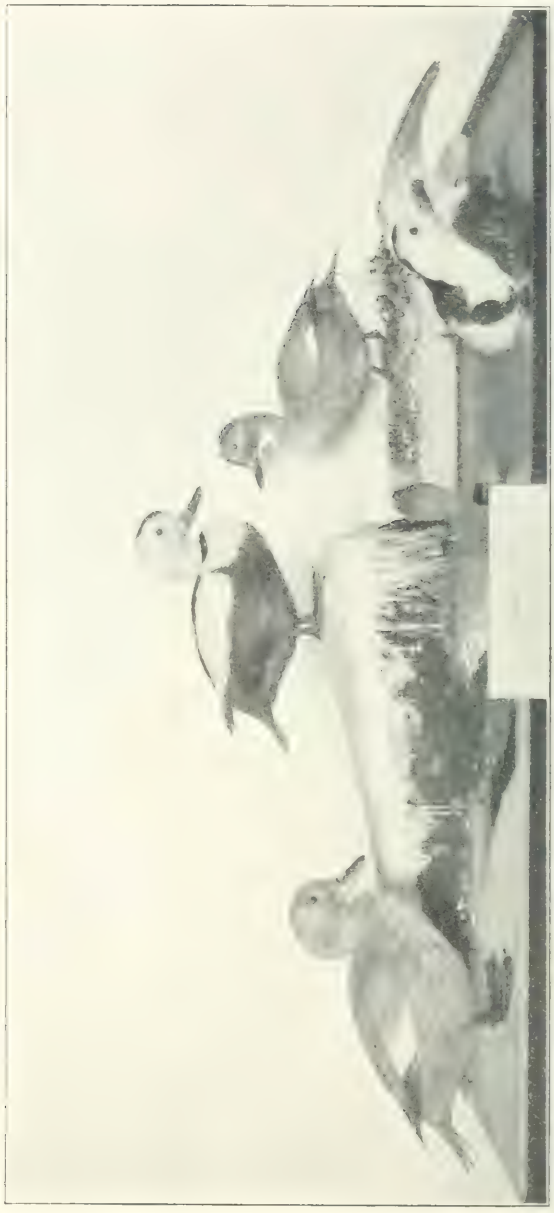


FIG. 341. *Camptorhynchus labradorius*, the Labrador duck, which became extinct during the latter half of the nineteenth century. It was formerly found along the eastern coast of North America, from Labrador to New Jersey. (From a photograph provided by the American Museum of Natural History.)

The Accipitres include the secretary bird or serpent eater of South Africa; the American vultures, great scavengers, feeding on carrion, including the turkey buzzard (Fig. 342), the California vulture, the tropical king vulture, and the condor, which is confined to the Andes and feeds on living animals as well as carrion; the vultures of the eastern hemisphere, carrion feeders found in Europe, Africa, and Asia; the eagles, which are

FIG. 342. *Cathartes*, a turkey buzzard or American vulture. (From a photograph provided by the American Museum of Natural History.

widely distributed over the world but of which there are only two species in North America, the golden eagle, also found in Europe and Asia, and the baldheaded eagle, confined to this continent; the true buzzards and their allies, widely distributed and with numerous representatives in this country. Two species of the true buzzards, genus Buteo, are known popularly in the eastern United States as hen hawks. To the Accipitres belong

also the osprey, or fishhawk, of which there is only a single representative, but widely distributed over the whole globe, the harriers, the kites, the true hawks (Fig. 343), and the falcons.

These two last groups are of interest because of their use in falconry or hawking, a sport which was most ardently followed

FIG. 343. *Falco peregrinus anatum*, the American duck hawk and wing. (From a photograph provided by the American Museum of Natural History.)

just before the invention of gunpowder and firearms; it is still carried on to some extent to-day in England and France, and to a considerable extent in Asia, which was the original home of the sport. The Accipitres are of some use to man as destroyers of vermin and as scavengers.

### Suborder 5. Psittaci

The Psittaci (Gr. *ψίττακος*, parrot) are the parrots. The beak is short and the upper is hooked, projecting over the tip of the

lower. Two of the toes, the first and fourth, project backward, the other two forward. They are mostly tropical birds, often

FIG. 344. *Bubo virginianus*, the great horned owl. (From a photograph provided by American Museum of Natural History.)

with the most brilliantly colored plumage, and varying in size from little species as large as a sparrow to the largest, which measures nearly a meter from tip of beak to tip of tail. From

remarkable powers of imitating human speech and various other sounds is familiar to every one. Different kinds of parrots have received various popular names, such as the owl parrots, the cockatoos, the parrakeets, the lories, the little love birds, and the large macaws.

### Suborder 6. Striges

The Striges (Lat. *strix*, owl), or owls, are sometimes included with the Accipitres and called the nocturnal birds of prey. They have eyes and ears remarkably well developed, and the eyes are surrounded by rather stiff, radiating feathers, which give them their characteristic appearance; the eyes look almost directly forward. The owls (Fig. 344) are very useful because of the large number of rats, mice, and other animals objectionable to man which they destroy. They are widely distributed over the globe, and some live in extremely cold countries.

### Suborder 7. Picariæ

The Picariæ (Lat. *picus*, woodpecker) constitute a heterogeneous collection of birds having their principal habitat in the tropics, although some are found in temperate zones as well. We can simply mention some of the more familiar members of the group, such as the plantain eaters, the cuckoos, the goatsuckers, the whip-poor-wills or nighthawks, the rollers, the bee eaters, the kingfishers, the hornbills, the toucans, with their huge beaks, the woodpeckers, the trogons, the swifts, and the humming birds. There are some four hundred species of the humming birds, and they are confined to the western hemisphere; most of them occur in Central and South America, but a few extend as far north as Canada.

## Order 2. Schizognathae

(Gr. *σχίζειν*, cleave, and *γνάθος*, jaw)

### Suborder 1. Pygopodes

The Pygopodes (Gr. *πυγή*, rump, and *πούς*, foot) are swimming birds with webbed feet. They include the grebes, which are to a

greater or less extent migratory. Sometimes the Pygopodes are included with two succeeding suborders, the Turbinares and the Gaviæ, in a single suborder called the Cecomorphæ; while others comprise the Pygopodes and the Gaviæ in the Cecomorphæ and recognize the Turbinares as a distinct group. For the present we may keep the three groups distinct.

### Suborder 2. Turbinares

The Turbinares (Lat. *turbo*, a top or cone) include the albatrosses, ocean birds with remarkable powers of flight, and the petrels, of which the most familiar are the stormy petrels, popularly called Mother Carey's chickens. The wandering albatross is the largest water bird in existence and is said to attain a stretch of wing of over four meters.

### Suborder 3. Gallinæ

The Gallinæ (Lat. *gallina*, hen) represent the group in the older system of classification known as the scratching birds. It is a very large group and probably includes more species used for food than any other group of birds. The young are precocious. Here belong the quails, partridges, and grouse.

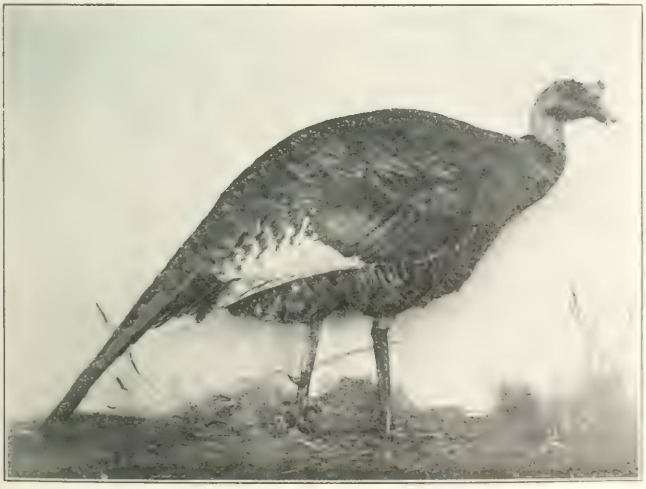


FIG. 345. *Meleagris*, a wild turkey of South America. (From a photograph provided by the American Museum of Natural History.)

Many of the grouse have special popular names, such as ptarmigan, the prairie hens or prairie chickens, the sage cock, and the ruffled grouse. The most important family of the Gallinæ, and the one which contains some of the most brilliantly colored birds in existence, is the Phasianidæ, comprising the Guinea fowls, the jungle fowls, and all the pheasants, such as the blood pheasants, the firebacks, the silver pheasants, and the golden pheasants; they are all essentially Asiatic birds. The turkeys are American birds (Fig. 345); one species is found in North America, one in Mexico, and one in Central America; they have brilliant metallic colors. Many of the most brilliant of the Asiatic pheasants have no common names in English, but the argus pheasant and the peacock pheasant are familiar. To this same family belongs our common domestic peacock, *Pavo cristatus*, which is a native of India. All our varieties of domestic fowls have descended from the jungle fowl of Asia and the West Indies.

### Suborder 4. Grallæ

The Grallæ (Lat. *grallæ*, stilt) are long-legged wading birds, usually without webbed feet. They include the bustards, the cranes, and the rails.

### Suborder 5. Gaviæ

The Gaviæ (Lat. *gavia*, a sea bird) are web-footed swimming birds, and most of them are good flyers as well. The loons, auks (Fig. 346), and puffins are confined to the northern hemisphere and prefer the colder waters of the North; they never enter the tropics. The great auk, *Alca impennis*, had very small wings and was incapable of flight; it inhabited both sides of the temperate portion of the Atlantic until 1844, when the last individuals were killed by man and the species became extinct. The gulls and terns likewise belong to this suborder and are scattered over the whole world.

### Suborder 6. Limicolæ

The Limicolæ (Lat. *limus*, mud, and *colere*, to inhabit) are sometimes included in the same group with the Grallæ; like them they are wading birds without webbed feet. They include

the plovers, the snipes, the sandpipers, the curlews, and the woodcock. Some zoologists also place the bustards here.

### Suborder 7. Pterocletes

The Pterocletes (Gr. *πτερόν*, wing, and *κλείς*, key) comprise only two genera and are popularly called sand grouse. They occur in Asia and in Africa, the greater number in the latter continent. They are good flyers.

FIG. 346. *Alca impennis*, the great auk, now extinct, and the smaller *Alca* (*Utamania*) *torda*, the razor-billed auk. (From a photograph provided by the American Museum of Natural History.)

### Suborder 8. Columbæ

The Columbæ (Lat. *columba*, pigeon) consist of the pigeons (Fig. 347) and doves. They are found all over the world and are most numerous in the eastern hemisphere, particularly in the islands of the Pacific and in Australia. They have a number of natural enemies, such as serpents and monkeys, which destroy their eggs, and it is notable that they are absent from countries where such animals abound. Every one is familiar with pigeons, and their shape and general appearance are so characteristic that no description here is necessary. They feed upon fruit and

seeds, and in drinking immerse the bill in the water and take a continuous draught, a method practiced by no other birds so far as known. The young are non-precocious and are carefully tended by the parents. The flesh of pigeons is very palatable, and in many countries they form an important article of food. Every student should read Darwin's account of his experiments in breeding domestic pigeons.

FIG. 347. *Columba livia domestica*, the common pigeon. (Photographed from a mounted specimen by the author.)

To this same suborder belong two birds which have become extinct within recent times. The more familiar of these is the dodo, *Didus ineptus* (Fig. 348), which lived in the islands of Rodriguez, Bourbon, and Mauritius in the Indian Ocean, in considerable numbers in the early part of the seventeenth century. It was a large bird, weighing from twenty to twenty-five kilos, with small wings and incapable of flight. It was killed for food, and through the influence of man and the domestic animals became extinct in the latter part of the seventeenth century. The other bird, the solitaire, *Pezophaps solitaria*, was somewhat larger than a turkey, and weighed about the same as the dodo; it, too, was incapable of flight. Its flesh was said to be very pala-

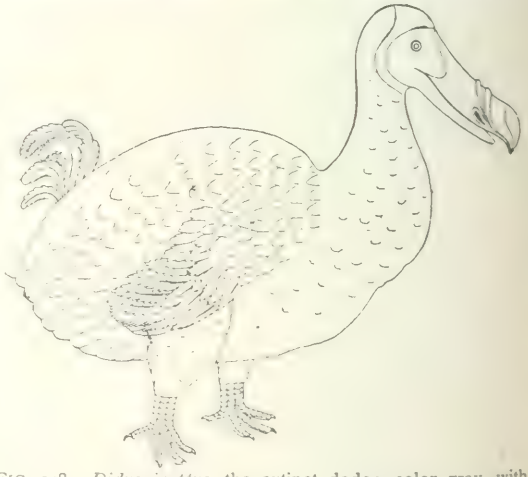


FIG. 348. *Didus ineptus*, the extinct dodo; color gray, with yellow wing and tail feathers; natural size, 80 cm. high; weight, 12.5 kg. (From Ludwig-Leunis' Synopsis der Thierkunde.)

table. Skeletons of this bird have been obtained from the island of Mauritius.

### Order 3. Ægitognathæ, or Passeres

All the birds considered up to this point comprise something less than one half the known species; all the remainder belong to the single order Ægitognathæ (Gr. *αἴγιθος*, sparrow, and *γνάθος*, jaw),

Fig. 343. *Plectrophenax nivalis*, the snow-bunting or snowflake. (From a [illegible] provided by the American Museum of Natural History.)

or Passeres (Lat. *passer*, sparrow). They are generally divided into five groups, and we may indicate some of the principal members of each in order to give a general idea of their components.

The first group consists exclusively of Australian birds. They include the two species of lyre birds, which in the male are provided with beautiful, lyrelike tails composed of sixteen rectrices. The brush or scrub birds also belong here, and are noteworthy because of their remarkable ability to imitate the sounds of other animals.

FIG. 350. *Melospiza fasciata*, the song sparrow. (From a [illegible] in the American Museum of Natural History.)

The second group consists of the broadmouths or broadbills, small birds not much larger than a sparrow, found in southeastern Asia and some adjacent islands, as well as in South America. There are only about a dozen species, and many are brilliantly colored.

The third group is a large one, about six hundred species, found all over the world in the tropics, and most numerous in America, where some of them extend into temperate regions. Some are brilliantly colored, but many are dull. They consist of the very numerous tyrant birds, the cock-of-the-rock, and the kingbirds.

The fourth group consists of the ant birds, some five hundred species confined strictly to Central and South America.

The fifth group is the largest of all and practically identical with the group of singing birds, the songsters of many zoölogists (Fig. 349). It is said, however, that no two zoölogists agree as to how the group should be subdivided. We may merely note the common names of some birds which represent more or less distinct subdivisions: larks, pipits, wagtails, forktails, thrushes, sparrows (Fig. 350), flycatchers, bluebirds, blackbirds, robins, nightingales, wrens, tailor birds, dippers, mocking birds, gnat

FIG. 351. *Paradisea*, male bird of paradise. (From a photograph provided by the American Museum of Natural History.)

catchers, swallows and martins, shrikes, waxwings, cedar birds, greenlets or vireos, tits, true orioles, bower birds, birds of paradise (Fig. 351), jays, magpies, nutcrackers, crows, starlings, honey eaters, sunbirds, creepers, warblers, tanagers, weaver birds, American orioles, grosbeaks, North American sparrows, finches, and canaries.

## CLASS VI. MAMMALIA

The Mammalia (Lat. *mamma*, breast), like the Aves, are warm-blooded Vertebrata, and just as feathers are characteristic of birds, so hairs are characteristic of mammals. Hairs are never

entirely absent except in some of the marine species, and even in such cases they are present during development; they consist entirely of epidermal cells. Frequently there are two kinds of hairs: the stiff contour hairs, which give the general shape to the body, and the shorter, soft, woolly hairs; in some instances the contour hairs are veritable bristles and spines, as in the hedgehog and porcupine. Usually the hairs fall out from time to time and are replaced by new ones.

Other structures also develop from the epidermis, chiefly through cornification, such as claws, hoofs, nails, some horns as in the rhinoceros, ox, and buffalo, the scales on the tails of rats and mice, and the large scales of the pangolins. In some mammals bony structures develop in the derma; these form the shell-like covering of the armadillo and the antlers of the deer and moose. The skin of mammals is generally pigmented; the outermost layer of the epidermis is cornified and comes away in small pieces. Glands are generally numerous in the integument, and there are two kinds, the sweat glands, largely excretory in function, and the sebaceous glands, which have an oily secretion which keeps the skin soft. The latter always occur in connection with the hairs and also on parts of the skin where hairs are absent. There are various other glands, which are modifications of these, the most important being the milk or mammary glands, from which the class derives its name. In the lowest mammals the ducts from these glands open directly at the surface of the skin, but in all the others there is an elevation forming a teat or nipple, and of these there may be from one to eleven pairs, arranged in two rows, either along the whole ventral side of the trunk of the body, or confined to either the thorax or the abdomen. The number corresponds in a general way to the maximum number of young that may be produced at a birth. Mammary glands are well developed in the female; they are present in the male, but rudimentary, and normally are non-functional. All the Mammalia have two pairs of appendages, except two of the marine orders, in which the pelvic limbs are absent; there is naturally very great variation in the form and size of the appendages, corresponding to the different uses to which they are put in different species.

The general shape of the body varies greatly, but we can gen-

erally distinguish four regions, head, neck, trunk, and tail (Fig. 352); but the neck may be practically absent, as in whales and their allies, and the tail may disappear as an external appendage, as in man. The head bears the mouth, which is provided with movable lips in all groups except the lowest, which have a

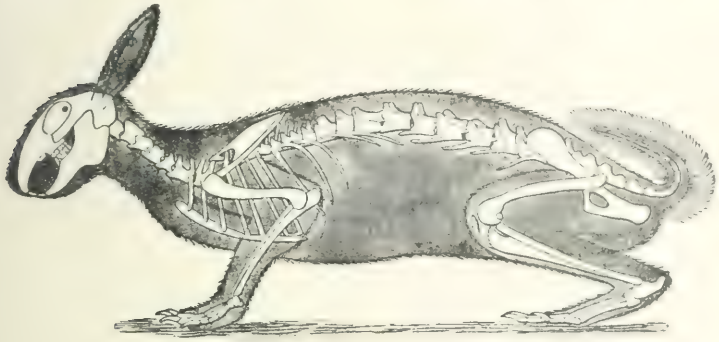


FIG. 352. *Lepus cuniculus*, the rabbit; lateral view of skeleton, with outline of body. (After Parker and Haswell.)

horny beak like that of some birds. The external nares are generally at the tip of the snout, and the olfactory organ is more highly developed than in any other class of vertebrates. The eyes are usually well developed and are provided with lids, but are non-functional in some species which live habitually in the dark; connected with them are the lachrymal or tear glands. External ears are usually well developed.

As the Mammalia are of particular interest, being the most highly developed group of animals and the one to which man belongs, we may give an epitome of the more important internal organs (Fig. 353). The axial skeleton consists of the skull and vertebral column; in the skull the sutures persist to a greater or less extent throughout life. Five regions can be distinguished in the vertebral column: the cervical region immediately succeeds the skull, and the first and second vertebræ are known respectively as the atlas and the axis; the skull rests on the atlas; the thoracic region succeeds the cervical, and each thoracic vertebra bears a pair of ribs; most of the ribs join the sternum on the ventral side of the body; next comes the lumbar region, where the vertebræ are without ribs; then the sacral region, com-

sisting of several fused vertebræ to which the pelvic girdle is attached; and this is succeeded by the caudal region. The vertebræ are separated from one another by elastic discs called the intervertebral ligaments. The pectoral girdle generally consists of only two distinct bones, the scapula, or shoulder blade, and the clavicle, or collar bone, and the latter is absent in many mammals; the pelvic girdle consists of three bones, as in all vertebrates above the fishes, one dorsal in position, the ilium, and two ventral, an anterior, the pubis, and a posterior, the ischium; the posterior appendage articulates at the point where these three bones meet. The bones of the appendages have the same general arrangement as in all the vertebrates above the fishes.

The muscular system is well developed, and the variations in the number, size, and shape of the individual muscles conform to the uses to which they are put in accordance with the habits of the different species. Of the nervous system we may note simply that the brain attains a higher degree of development here than in any other group of animals. The body-cavity of the Mammalia differs from that of any other group of the Vertebrata, in that it is completely divided into two parts by a muscular membrane, the diaphragm, which separates it into an anterior chamber, the thoracic cavity, containing the heart and the lungs, and a posterior chamber, the abdominal cavity, containing the remaining viscera.

The digestive tract consists of several regions. The mouth is usually provided with teeth, which are confined to the jawbones; in some cases the teeth are nearly all the same size and shape, but more or less conical; teeth of this sort constitute homodont dentition, and they vary in number from one to two hundred in different species. In most mammals, however, the teeth are of different shapes, constituting heterodont dentition; the most anterior teeth are called incisors; they are usually bounded by the fanglike canines, one on each side in each jaw, and back of the canines are the double teeth, of which the more anterior are called premolars, the more posterior, molars. In most mammals there are two sets of teeth, the milk dentition of temporary teeth, which eventually fall out, and the permanent teeth, which succeed them; there are rarely more than forty-four of these.

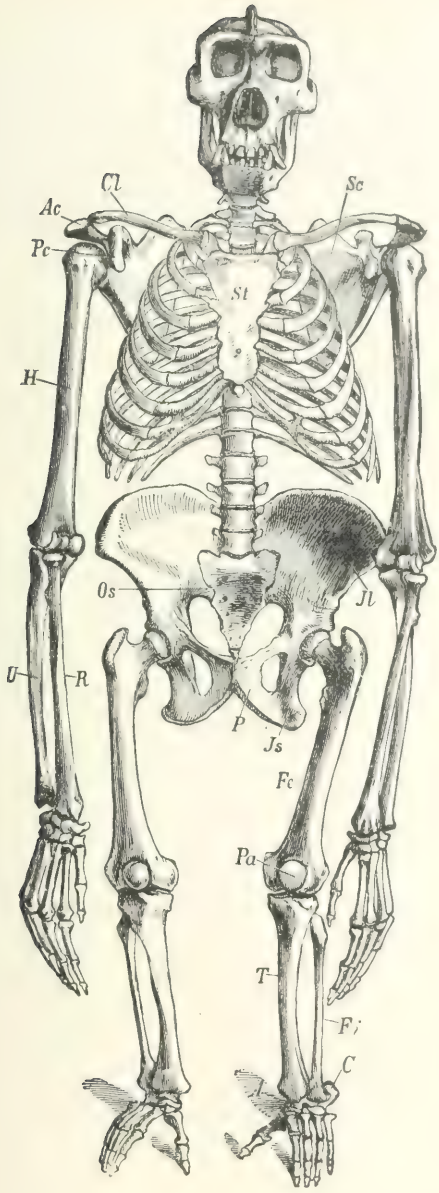



FIG. 353. *Gorilla engena*, skeleton. *A*, astragalus; *Ac*, acromion; *C*, calcaneum; *Cl*, clavicle; *Fc*, femur; *Fi*, fibula; *H*, humerus; *Jl*, ilium; *Js*, ischium; *Os*, sacrum; *P*, pubis; *Pa*, patella; *Pc*, coracoid process; *R*, radius; *Sc*, scapula; *St*, sternum; *T*, tibia; *U*, ulna. (After Claus and Sedgwick.)

The teeth are always inserted into cavities or sockets in the jawbones. The cheeks are very distensible in some cases, as in rodents and some apes, and serve as temporary food pouches. Salivary glands open into the mouth in almost all mammals, and their secretion assists in the digestion of the food. A tongue is always present, though it may be immovable, and is the principal organ of taste, a special sense which is more highly developed here than in any other class. The œsophagus extends backward from the mouth and, passing through the diaphragm, enters the abdominal cavity, where it joins the stomach, a large, saclike organ, which in the ruminants, animals which chew their cud, such as the oxen and sheep, is divided into four compartments. The stomach connects with the small intestine, which is generally very long and greatly coiled; the portion of it which immediately succeeds the stomach is called the duodenum, and receives the ducts from two large glands, the pancreas and the liver. The small intestine opens into the large, which is both larger and shorter, and passes into the rectum, which terminates in the anus; only in the lowest mammals is there a cloaca. Attached to the large intestine near the point at which the small intestine joins it is a blind sac, the vermiform appendix. In addition to the organs just mentioned, the abdominal cavity contains the spleen and the urogenital organs.

At the back of the mouth is the glottis, which can be closed during the passage of substances into the œsophagus by a lidlike membrane, the epiglottis; the glottis opens into the larynx, the organ of voice, which forms the anterior end of the trachea, or windpipe. At its posterior end the trachea divides into two bronchi, which pass into the two lungs. Between the lungs lies the heart, which has the same general structure as in birds, with four chambers, and the course of the blood through it is the same. Opening into the blood system is another system of vessels, the lymphatic, containing a nearly colorless fluid; it is found in all the other vertebrates as well. The color of the blood is due, as in all the Vertebrata, to colored cells; in all the other classes, however, these cells are nucleated like any other cells in the body, but in the Mammalia the colored blood corpuscles are without nuclei. The two kidneys lie in the lumbar region in the abdominal cavity; from each passes off a duct, the

ureter, which opens into the dorsal side of the urinary bladder; from the urinary bladder a single duct, the urethra, passes to the outside.

The male reproductive organs consist of the two testes, which have variable positions in the different mammals; in some, such as the whales, they lie in the abdominal cavity in the region of the kidneys; in some, such as the elephants, they pass backward to the region of the urinary bladder; the latter condition is found also in rodents, bats, and some others except during the breeding season, and then they pass into temporary pockets formed by evaginations of the ventral abdominal wall and called the scrotal sacs; in almost all other mammals they lie permanently in the scrotal sacs and cannot normally pass back into the abdominal cavity; the two scrotal sacs may remain distinct or they may fuse into one, the scrotum, but the internal cavities remain distinct. Many ducts pass off from each testis, uniting in a single *vas deferens* for each, which opens into the urethra near the bladder. The urethra receives also the ducts from the prostate and Cowper's glands, whose secretions are mingled with the spermatozoa at the time of ejaculation. The urethra is inclosed in an erectile penis. The two ovaries lie near the posterior portion of the abdominal cavity; when the ova are mature they pass into the oviducts, or Fallopian tubes as they are called in the Mammalia, and these lead into the uterus; there may be two uteri or the two may be fused into one; the uterus opens into the vagina, which leads to the outside. One group of mammals is oviparous, the group to which the duckbill belongs, laying eggs about two centimeters in diameter; but all the rest are viviparous, and the ova, which are extremely small, practically microscopic, develop within the uterus.

In the course of development an amnion and an allantois are formed as in reptiles and birds, and there is almost always an intimate connection between these membranes and the wall of the uterus. The membranes are connected with the ventral body wall of the embryo or fetus by means of a stalk, the umbilical cord, through which blood vessels pass, and the branches of these blood vessels in the membranes come into close contact with the maternal blood vessels of the wall of the uterus; thus by osmosis the nutritive fluids pass from the mother to the

fetus, — there is never a direct continuity of the cavities of the maternal and fetal vessels. This organ of nutrition, consisting in part of portions of the fetal membranes and in part of portions of the uterine wall, is termed the placenta, and is found in various forms in most mammals. In some the membranes separate readily from the wall of the uterus at birth; in others the connection is so intimate that a part of the uterine lining is torn away at birth and forms the decidua or afterbirth. The period of development or gestation, as it is technically termed, varies much, from three weeks in some mice to twenty months in the elephant; there is also much variation in the number of young that may be born at one time. A few mammals are monogamous, but this is rare.

While the majority of the Mammalia are land animals, some live most of the time in the air and others are wholly or partly aquatic. Many of them are gregarious; in cold countries many pass into a winter sleep; they then take no food, the temperature of the body is lowered, and the heart beat and respiration are slower. One of the most striking characteristics of this class is found in the care taken of the young, which are generally born in a more or less helpless condition, and are fed and cared for by the parent until they are able to care for themselves.

Fossil remains of the Mammalia are numerous, and many extinct species were of gigantic proportions. Concerning the origin of the group there is considerable doubt; through fossils there is a distinct relationship to the Reptilia, and through certain anatomical and embryological characteristics a relationship with the Amphibia may readily be established.

### SUBCLASS I. ORNITHODELPHIA, OR MONOTREMATA

The Ornithodelphia (Gr. *ὄρνις*, bird, and *δελφύς*, womb), or Monotremata (Gr. *μόνος*, single, and *τρῆμα*, opening), also called the Prototheria (Gr. *πρῶτος*, first, and *θηρίον*, beast), constitute a small group of mammals found to-day only in Australia and the adjacent islands of Tasmania and New Guinea; fossil remains, however, have been found in America and Europe. They differ from all other Mammalia in having a cloaca and consequently a single cloacal opening to the outside instead of dis-

tinct anal and urogenital openings; and, further, they are the only mammals which are oviparous.

There are only two families; the first is represented by a single animal, *Ornithorhynchus paradoxus* or *anatinus*, known popularly as the platypus, duckbill, or duckmole (Fig. 354). Its jaws resemble a duck's bill, and there are no teeth in the adult, although they are found in the embryo. The duckbill grows to be about forty-five centimeters in length from the tip of the bill to the tip of the tail; it is a dark brown in color and covered with woolly hairs, and longer, stiff contour hairs. The feet are webbed and the toes are provided with claws, as the animal is

FIG. 354. *Ornithorhynchus anatinus*, the duckbill. (After Vogt and Sprecht, from Parker and Haswell's Manual.)

largely aquatic and uses its feet for swimming and also for burrowing. In the male each hind foot bears a sharp, projecting spur. The eyes are small and there are no projecting ears. They feed on worms and various small aquatic animals and have cheek pouches in which the food may be temporarily stored. They burrow a chamber in the ground near the water, line it with leaves, and thus fashion a nest in which the eggs are deposited and the young cared for.

The second family is not strikingly like the first in general appearance; it is represented by the spiny ant-eaters, of which there are several species (Fig. 355). One species, *Echidna hystrix*, is about thirty centimeters long; others are somewhat larger. The beak is much shorter and narrower than in Ornithorhynchus, the tail is very rudimentary, the feet are not

webbed, and there are numerous spines among the hairs; in one species these spines are over seven centimeters long. They are not aquatic in habit, but resemble the duckbill in burrowing, and have the toes provided with sharp claws. As their popular name indicates, they feed largely on ants and other small insects,

FIG. 355. *Echidna oculeata*, the spiny ant-eater. (After Vogt and Sprecht, from Parker and Haswell's Manual.)

and for this purpose have a long, slender, and protrusible tongue. During the breeding season a temporary pouch is formed of the skin on the ventral side of the body, in which the eggs are placed when laid, and there the young remain for some time after hatching. After the breeding season the pouch disappears. In all of the Monotremata nipples are absent, and the ducts from the mammary glands open directly on the surface of the skin.

## SUBCLASS II. DIDELPHIA, OR MARSUPIALIA

The Didelphia (Gr. δίς, double, and δελφύς, womb), or Marsupialia (Lat. *marsupium*, pouch), sometimes called the Metatheria (Gr. μετά, between, and θηρίον, beast), are commonly distinguished by the marsupium, or pouch, which is attached to the posterior part of the ventral abdominal wall; but this pouch is sometimes rudimentary and sometimes absent, and we have already noted that a similar pouch occurs in some of the Monotremata. This class is distinguished from the preceding by the fact that there is no true cloaca, but distinct anal and urogenital

openings; and from the succeeding class by the structure of the genital ducts in the female, for there are two distinct uteri and two vaginæ, a condition which obtains in no other group of mammals.

The Didelphia present the widest possible variation in habits of life and size: some are herbivorous, some carnivorous, others omnivorous, others insectivorous; some are aquatic, some terrestrial, some arboreal; they range from animals the size of a rat to the giant kangaroos, which when standing erect are over two meters in height, while some fossils attained the size of a rhinoceros. The fur is generally soft and long. Teeth are always present and all are permanent except two in each jaw, which fall out and are replaced by others. The mammary glands are in the abdominal region; there are thirteen teats in all the opossums and four in the kangaroos and other marsupials; they are always within the marsupial pouch. In the male the scrotum occupies the position of the marsupium, and is consequently anterior to the penis. The young are born in a very immature condition, and are placed by the mother in the marsupium, where they adhere tightly to the teats, from which they derive the nutriment for their further development. In the largest marsupials, the kangaroos, the period of gestation is only from twenty to forty days, and at the end of that time the embryo is only about two centimeters long; then it remains in the marsupial pouch for about eight months, until it can take care of itself. The brain of the Marsupialia is relatively small; they are for the most part timid animals of nocturnal habits. Their geographical distribution is somewhat remarkable: the opossums are confined to South America and the southern por-

FIG. 356. *Didelphys virginiana*, the Virginian opossum. (After Vogt and Specht from Parker and Haswell, Manual.)

tion of North America; all the remaining families are found only in Australia and adjacent islands, although fossils occur in Europe as well.

The family Didelphidæ, the opossums, includes all the American marsupials. The majority are not larger than a rat, but our common Virginian opossum, *Didelphys virginiana* (Fig. 356), attains the size of the domestic cat; it has a long, scaly, prehensile

FIG. 357. *Petrogale xanthopus*, the rock wallaby, closely allied to the kangaroos. (After Vogt and Sprecht, from Parker and Haswell's Manual.)

tail. This species, which is one of the largest opossums, has a marsupium; the period of gestation is from twenty-four to twenty-eight days, and of lactation two months. Some South American opossums which have no marsupial pouch carry the young upon their backs, after they are old enough to leave the teats. Nearly all are insectivorous or carnivorous in habit, and all are arboreal except the water opossum of Brazil, which is aquatic and has

the hind feet webbed. The remaining marsupials are confined to the region of Australia, and include such types as the wombats, little burrowing animals about sixty centimeters long, with large head, short neck and legs, and rudimentary tail; the koala or native bear of New South Wales, arboreal in habit; the phalangers, little arboreal animals, ranging from eight or ten centimeters in length to the size of a cat, having long, prehensile tails; the burrowing bandicoots, about as large as a small rabbit; the kangaroos and their allies (Fig. 357), which are the largest and the most numerous of the Marsupialia and have the hind legs and tail very well developed, — the giant kangaroo, *Macropus major*, can make leaps of five or six meters when pursued; the Tasmanian devil, a carnivorous genus about the size of a badger; and the zebra wolf or pouched dog, about the size of a wolf, carnivorous and nocturnal in habit.

## SUBCLASS III. MONODELPHIA, OR PLACENTALIA

The Monodelphia (Gr. *μόνος*, single, and *δελφύς*, womb), or Placentalia (Lat. *placenta*, a cake), are sometimes called the Eutheria (Gr. *εὖ*, well, and *θυρίον*, beast), — the Metatheria and Eutheria being then collectively known as Theria, while some zoölogists apply the name Eutheria to both groups. They may be distinguished by the fact that the vagina is always single; the uterus may be single or it may be more or less com-

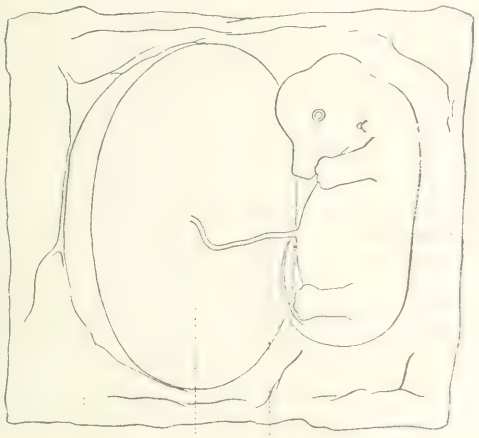


FIG. 358. *Mus decumanus*, the common rat, [illegible] which the embryonic membranes have been removed; natural size, 13 millimeters long. *e*, embryo [illegible] position in the concavity of the placenta; *p*, placenta, which is shaped like a meniscus; *um*, umbilical cord, which contains the blood vessels passing between the embryo and the placenta; *ut*, wall of the uterus, cut open and laid back. (Drawn from a preserved specimen, by the author.)

pletely divided into two, and is then called a two-horned uterus. The embryo, or fetus, is always nourished in the uterus by means of a placenta (Fig. 358). A cloaca and a marsupial pouch are never present. Nine orders of Monodelphia are pretty generally recognized by zoologists, but the arrangement of these orders, with the exception of the lowest and the highest, is a matter of considerable dispute.

### Order 1. Edentata

The Edentata (Lat. *edentatus*, toothless) are characterized by the absence of the incisor teeth, and in some representatives of the order all the teeth are lacking. They are for the most part tropical mammals, inhabiting the southern hemisphere;

FIG. 359. *Orycteropus capensis*, the aard-vark. (After Vogt and Sprecht, from Parker and Haswell's Manual.)

only one species extends as far north as the United States. The brain is small, they are sluggish in habit and appear very stupid. Two families occur in Africa: one is the aard-vark or ground hog (Fig. 359) of South Africa, a burrowing animal about the size of a hog, sparsely covered with stiff hairs; it remains quiet during the day and emerges at night to feed on ants and

other insects. The other family consists of the pangolins (Fig. 360), which are found in southern Asia also; they are sometimes called the scaly ant-eaters, as the body is covered except on the ventral side with overlapping horny scales; the ventral surface

FIG. 360. *Manis pentadactyla*, the scaly ant-eater or pangolin. (After Vogt and Specht, from Parker and Haswell's Manual.)

is hairy. Teeth are wanting in the pangolins, and they possess a long, slender tongue, which they use in catching the insects on which they feed; they are commonly from half a meter to a meter long, while the tail is generally from a third to one half the entire length.

FIG. 361. *Myrmecophaga jubata*, the giant ant-eater of South America. (From a photograph provided by the American Museum of Natural History.)

All the rest of the Edentata belong to America. The hairy ant-eaters (Figs. 361 and 362) have the body covered with long hair; teeth are absent, and there is a long, slender, protrusible tongue for capturing insects; they vary in size, the largest being a meter and a half long. The sloths (Fig. 363) are strictly

FIG. 362. *Tamandua tetradactyla*, the Tamandua ant-eater. (From Shipley and MacBride's Zoölogy.)

arboreal animals, hanging upside down from the branches of the trees on whose leaves they feed; the body is covered with long hair; they are provided with teeth and have a very short

FIG. 363. *Cholœpus didactylus*, the two-toed sloth. (After Vogt and Sprecht, from Parker and Haswell's Manual.)

tail. Some species are two-toed and some are three-toed, and all have the toes armed with long claws; they well deserve their name, as they are excessively sluggish in habit. The living

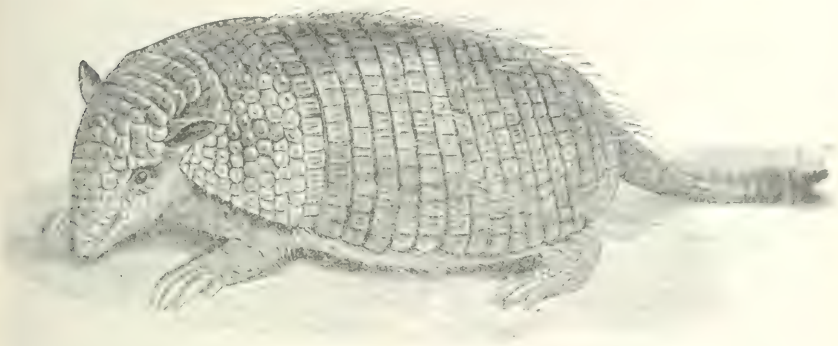


FIG. 364. *Tatusia novemcincta*, the six-banded armadillo. (After Voigt and Specht, from Parker and Haswell's Manual.)

species do not attain a great size; but some fossils, such as the Megatherium, rivaled the modern elephant. Lastly we have the armadillos (Fig. 364), characterized by having the body protected by a sort of shell which consists of bony dermal plates

FIG. 365. *Glyptodon clavipes*, a fossil Edentate resembling the armadillos. (After Owen, from Parker and Haswell's Text-book.)

covered by the cornified epidermis. Between the plates and on the ventral side of the body are scattered hairs. On the trunk there are usually a large anterior plate, a large posterior one, and

a variable number of smaller, bandlike plates between, while the head and tail are protected by numerous small plates. Some of the armadillos can roll themselves up into a ball, thus protecting the soft parts on the ventral side of the body. One species extends as far north as Texas, the nine-banded armadillo, which has eight or nine intermediate plates; it attains a length of seventy-five centimeters. The armadillos are provided with teeth, some having as many as one hundred; they are nocturnal in habit and carnivorous. While the living species are never very large, we have fossils which attained a length of over three and a half meters and had the shell in a single piece on the back, resembling the carapace of the turtles (Fig. 365).

### Order 2. Sirenia

The Sirenia (Lat. *siren*, a siren) are large, aquatic mammals known popularly as the sea cows. They are covered with a thick skin, which is naked in some cases and in others provided with a few scattered hairs. The external nasal openings are near the anterior end of the head, the eyes are small, and external ears are absent; there is no externally differentiated neck. The anterior appendages are finlike and the posterior are absent, while the posterior end of the body is expanded horizontally into a flat tail fin. There are two mammary glands on the thorax. The brain is small, the teeth consist of only incisors and molars, the testes lie permanently in the abdomen, and the uterus is two-horned. The bones are remarkable for their great density and weight. Though of considerable size, ranging commonly from three and a half to six meters in length, they are perfectly harmless animals, living along the shores of tropical oceans and sometimes ascending rivers for some little distance. They feed exclusively on seaweeds and river grasses, and their flesh, especially in the young, is largely eaten by man. The manatees are the sea cows which inhabit the tropical coasts of America and Africa; the dugongs are found in the Indian Ocean. Formerly there was a northern sea cow found in the North Pacific, very interesting because of the entire absence of teeth; it was much hunted for food by sailors and was exterminated about the middle of the eighteenth century. There are several fossil genera of sea cows.

## Order 3. Cetacea

The Cetacea (Gr. κῆτος, whale) are aquatic mammals and comprise the whales, porpoises, and dolphins. The majority live exclusively in salt water, but some enter the mouths of rivers and may ascend them for a variable distance; others, like the dolphins of the Amazon and the Ganges, are confined to fresh water. The general shape of the body is fusiform, more or less fishlike, covered with a thick, naked skin; hairs are confined to a few bristles about the mouth, and even these may disappear in the adult. There is no externally marked neck to separate the head from the trunk; the anterior appendages have the form of flippers or paddles, while the posterior are invariably absent. Often there is an unpaired median dorsal fin, which, however, does not have a skeletal support like that in the fishes. At the posterior end of the body the tail is flattened and expanded horizontally into two lobes, the "flukes." The head is often very large, in some cases being a third of the total length of the body. The mouth is usually very wide; the eyes are relatively small; the auditory opening is very small, and there is no external ear. The external nasal openings are on the top of the head; in the whalebone whales there are, as in other mammals, two external nares, but in all the other Cetacea the two are united into one; the nasal openings in this order are often called spiracles or blowholes, since the expired air carries aqueous vapor with it, so that when the animal breathes it appears to blow water from its nostrils. There are two mammary glands, which lie near the external genital opening.

Beneath the skin is a thick layer of fat, the "blubber," which serves to maintain the high temperature of the body. The bones are light and spongy, and so differ strikingly from the bones of the Sirenia. Teeth when present are homodont and very variable in number in different species. The tongue is thick, fleshy, and immovable. The lungs are very large, and the thoracic cavity extends far back in the body. The testes are abdominal in position and the uterus two-horned. The Cetacea feed upon other animals; they include the largest living animals and comprise about two hundred species, which

are readily divisible into two suborders according to the presence or absence of teeth. We may note a few of the common and more interesting species, considering first those which have teeth; in these there is always a single external nasal opening.

Of the smaller toothed whales the most common are the following: the two-toothed whales living in the waters about Australia and New Zealand, which are from four to six meters in length; the white whale, named from its yellowish white color, which lives in the northern Atlantic and Pacific waters and grows to be about five meters long; the narwhal, which in the male has one of the teeth in the upper jaw excessively long, and projecting forward, forming a tusk from two and a half to

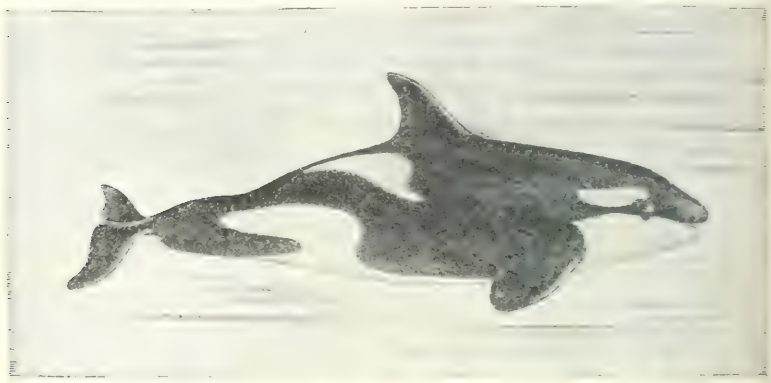


FIG. 366. *Orca gladiator*, the killer. (After True, from Parker and Haswell's Manual.)

three meters long, while the body of the animal is only from four to four and a half meters in length — it inhabits the Arctic seas; and finally the killers (Fig. 366), belonging to the genus Orca, which have a maximum length of from four and a half to six meters and are found in both the Atlantic and the Pacific. The last are extremely destructive animals, killing more than they can eat, feeding on young seals, young porpoises, fishes, and even attacking and killing some of the largest whales, which they overpower by their numbers.

To the toothed Cetacea belong also the porpoises and dolphins; these two popular terms are used interchangeably, but the true porpoises have a rounded head, while the true dolphins

have a longer and sharper snout. The bay porpoise lives along the shores and in the mouths of rivers, and is one of the smallest of the Cetacea, rarely exceeding a meter and a half in length. The dolphin, *Delphinus delphis* (Fig. 367), is abundant in the Mediterranean, along the western coast of Europe, and in the warmer portions of the Atlantic; they are often seen in

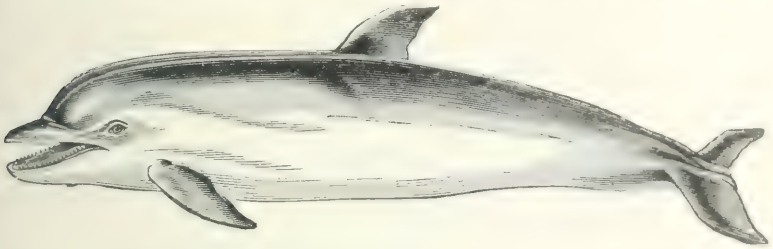


FIG. 367. *Delphinus delphis*, the common dolphin. (From Claus and Sedgwick's Textbook.)

considerable numbers, leaping in graceful curves from the water. The largest toothed whale is the sperm whale, *Physeter macrocephalus*; the male may attain a length of twenty-five meters; its teeth are confined to the lower jaw; the head is very large, about a third of the total length of the body. The sperm whale is extensively hunted, not only for its blubber, but also for the liquid oil and spermaceti which are found in a large cavity in the head. It is found in all oceans which are not icy, being more abundant in the southern hemisphere. Its food consists largely of Cephalopoda, and under certain conditions undigested squids become concretionary in the intestines and form the ambergris largely used by the perfumers.

The toothless whales never have functional teeth in the adult, and are known commonly as the baleen or whalebone whales, because the upper jaw is provided with many rows of vertical, horny plates with fringed edges; there are usually many hundred such plates (Fig. 368). These supply the whalebone of commerce, and during life are used by the animal in securing its food. It swims along with open mouth, taking in large quantities of pelagic Crustacea and Mollusca, and then, closing its mouth, the water is forced out between the fringes, and the captured animals, held as in a sieve, are thus swallowed. On the western coast of North America the California gray whale

is one of the commonest baleen whales. It migrates southward during the autumn and northward in the spring. In the winter the females enter lagoons along the shore to bring forth their young. These whales are from twelve to thirteen meters in length. Another whale of interest which occurs in the Pacific off the coast of California is the sulphur-bottom, interesting because it is the largest living animal; it is said to attain a

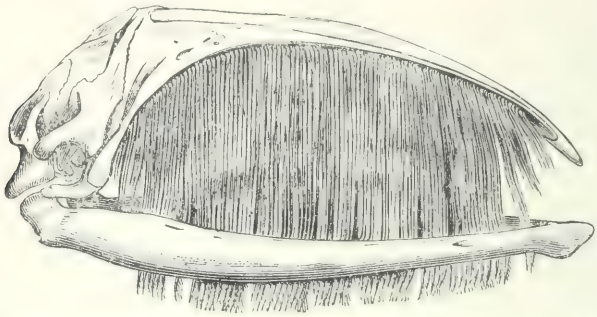


FIG. 398. *Balæna mysticetus*, the whalebone whale; skull with whalebone. (From Claus and Sedgwick's Text-book.)

length of about thirty meters. The whale which has been the longest hunted, and yields the most oil and the most and best whalebone, is the Greenland whale or bowhead. A good-sized individual of this species measures fifteen meters in length, though they have been taken nearly twenty meters long. It lives only in icy waters. The right whale of the North Pacific is a trifle larger, and is also extensively hunted.

### Order 4. Ungulata

The Ungulata (Lat. *ungula*, claw or hoof) have the digits, of which there may be from one to five, provided with horny hoofs or blunt nails. They include such types as the horse, tapir, rhinoceros, pig, camel, deer, cattle, and the elephant. All are terrestrial animals except the hippopotamus, which is amphibious in habit, and almost all are herbivorous. The teeth are heterodont, but the dentition is often incomplete, some teeth being absent from one or both of the jaws, and the clavicle is usually lacking. The Ungulata are sometimes divided into two groups, the first or true Ungulata comprising all the animals with well-developed hoofs, either entire or cloven, and the second consist-

ing of the elephants and a little animal called the Hyrax. Relying on the structure of existing animals, these two groups were long regarded as distinct orders by zoologists; but within recent years the study of the numerous fossils which have been discovered has revealed a sufficiently close relationship between the two to place them both in the same order. The more striking characteristics may be considered best under the four suborders into which the group is divided.

### Suborder 1. Perissodactyla

The Perissodactyla (Gr. περισσός, odd (in number), and δάκτυλος, finger or toe), or odd-toed Ungulata, are distinguished by the fact that the third digit always forms the axis of the foot; it may be the only digit developed, or the second and the fourth and sometimes the fifth may also be present (Fig. 369 *e* and *f*).

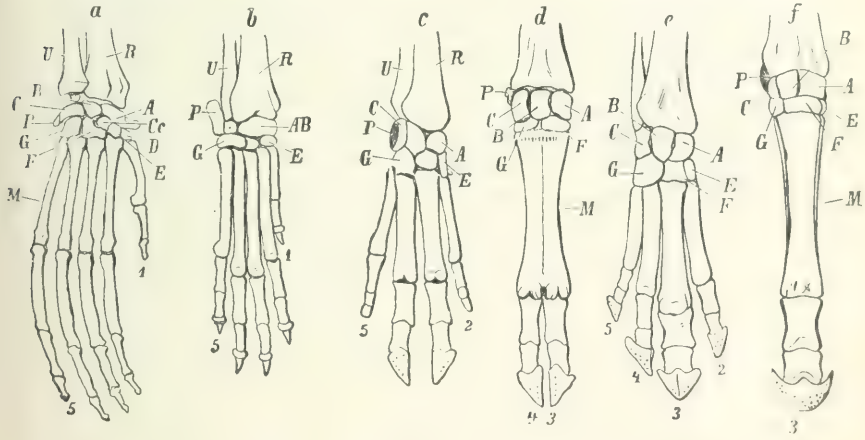



FIG. 369. Skeleton of the hand of: *a*, orang-utang; *b*, dog; *c*, pig; *d*, ox; *e*, tapir; *f*, horse. *A*, scaphoid; *B*, semilunar; *C*, cuneiform; *Cc*, centrale carpi; *D*, trapezium; *E*, trapezoid; *F*, magnum; *G*, unciform; *M*, metacarpus; *P*, pisiform; *R*, radius; *U*, ulna. (From Claus and Sedgwick's Text-book.)

There is always a good-sized hoof about the end of each digit, the individual walking on the tips of its toes. The mammary glands are always few in number, and the teats are far back on the abdomen; the testes always lie in a scrotum. There are three types of Perissodactyla, represented by the horse, the tapir, and the rhinoceros.

The horses all belong to the genus Equus, and, scientifically considered, include the asses and the zebras (Fig. 370). They have a soft, hairy skin, with a longer or shorter mane on the dorsal side of the neck, and either a bushy tail, as in the domestic horse and the quagga of South Africa, or a smooth tail with a brush near the tip, as in the ass and the zebra. Only the

FIG. 370. *Equus zebra*, the zebra. (From a photograph provided by the American Museum of Natural History.)

third digit is developed, but the second and fourth are represented by the "splint" bones of the skeleton, although these are not normally apparent externally. The various species will interbreed freely, but the offspring are not generally fertile. The mule is the offspring of the mare and the male ass; the hinny of the stallion and the female ass. The horse is found in its natural wild state to-day only in Asia and Africa, although fossil

remains are very numerous in America, and its ancesters have been traced back as far as the little Eohippus, about the size of a fox, which has four toes with a rudimentary fifth on its front feet, and three on its hind feet. The domestic horse is *Equus caballus*. The ass, *Equus asinus*, lives wild in Asia and Africa; the quagga and the zebra are confined to Africa and are conspicuous because of their handsome stripes.

The tapirs are found in southeastern Asia, including India and some of the East Indies, and in Central and South America.

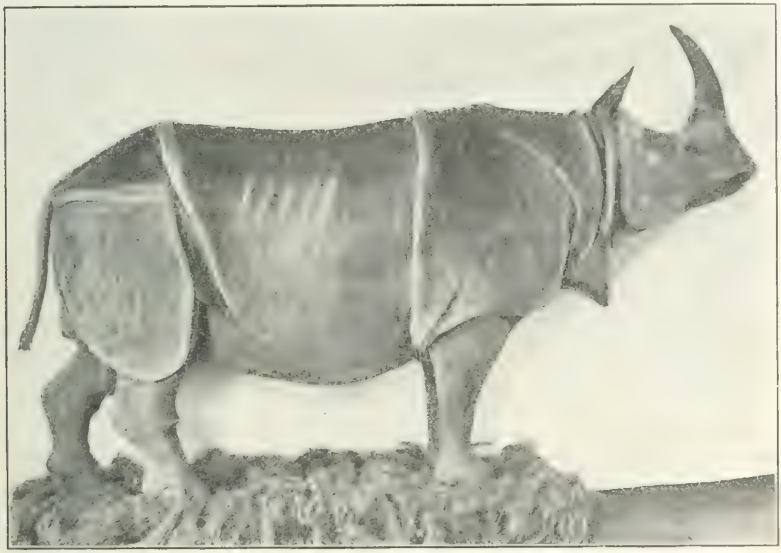


FIG. 371. *Rhinoceros unicornis*, the Indian rhinoceros. (From a photograph provided by the American Museum of Natural History.)

They have a soft skin with short hair and a very rudimentary tail; the upper lip is elongated into a sort of proboscis; the fore feet have four toes, the hind feet three. They feed upon the leaves and young shoots of shrubs and trees. The largest species is found in India; it attains a length of nearly two and a half meters, and a height at the shoulder of almost a meter.

The rhinoceroses (Fig. 371), of which there are six living species, differ strikingly from the horses and tapirs in having a very thick skin, often characteristically folded into large shields or plates, and with few hairs, and in having one or two horns

on the median line of the snout. These horns are made up of very many fiberlike bodies, which have the structure of hairs. Because of its thick skin the rhinoceros was formerly grouped with the hippopotamus and the elephant under the name of Pachydermata (Gr. *παχύς*, thick, and *δέρμα*, skin); they are now known to belong to three distinct groups. The fore feet of the rhinoceros bear three or four toes, the hind feet three. It lives in Africa, southeastern Asia, and some of the East Indies. The different species vary much in size, and the horns range from a few centimeters in length to over a meter. In the two-horned species the anterior horn is the longer.

### Suborder 2. Artiodactyla

The Artiodactyla (Gr. *ἄρτιος*, even (in number), and *δάκτυλος*, finger or toe), or even-toed Ungulata, are distinguished by having the axis of the foot between the third and fourth digits, which are equally well developed, thus giving rise to the cloven hoof (Fig. 369 *c* and *d*). The second and fifth digits may also be present. The teats may be few in number, from two to four, and situated on the posterior portion of the abdomen, or they may be numerous and extend in two lines along the trunk; the testes always lie in a scrotum. The incisors and canines are often absent from the upper jaw, and the stomach is complex, consisting of more than one chamber, and thus differing from the stomach of the preceding suborder, which is always simple. For our purpose the Artiodactyla may be divided into two groups, the first consisting of the hogs and their allies, and the second of the ruminants, or animals which chew their cud.

In the true hogs the canines are greatly developed, often forming huge tusks; they include the domestic pig, *Sus scrofa domesticus*, the wild boar, *Sus scrofa*, which extends from India to western Europe and northern Africa, and the hideous wart hogs of Africa. Related to the true pigs are the peccaries, abundant in South America, and extending into Mexico and Texas. In New Guinea and India live the pygmy hogs, genus Porcula, not quite half a meter long, and weighing only four or five kilos. The hippopotami live in Africa and possess two species, of which the larger, *Hippopotamus amphibius*, may

attain a length of four and a quarter meters, with a skin nearly five centimeters thick.

The ruminants comprise by far the largest number of Ungulata; there are usually no incisors or canines in the upper jaw, and the stomach consists of several chambers, usually four. The food, which is vegetable, when first swallowed, passes from the œsophagus into the first chamber of the stomach, then into the

FIG. 372. *Camelus bactrianus*, the camel. (From Brehm's Thierleben.)

second, and after a time goes upward through the œsophagus to the mouth again, where it is masticated; then it passes to the third stomach, the opening into the first and second being temporarily closed, and finally into the fourth and thence to the small intestine. The camel family has only the third and fourth digits present, and the toes are provided with fleshy pads on which the animal walks; it includes the genus Camelus (Fig. 372), living in Asia and Africa, with two species, the one-

humped dromedary and the two-humped camel. The latter is a native of Central Asia and larger than the dromedary; the humps are largely fatty masses, which serve as a reserve food supply. Some years ago camels were imported into the United States for use on our Western deserts, and are now quite abundant in New Mexico, Arizona, and Nevada. The only native

FIG. 578. [illegible] specimen from Alaska. (From a photograph [illegible] by the American Museum of Natural History.)

American representatives of this family consist of four species of the genus Auchenia, living in western South America, of which the most familiar are the llama and the alpaca.

The remaining ruminants are generally provided with antlers or with horns; the former are true bony structures, covered at first with the soft, hairy skin, called popularly the "velvet,"

which is later rubbed off; the latter consist of a bony core, over which is a chitinous layer, the external horn. Antlers develop only in the male, except in the reindeer, where they appear in both sexes and are annual structures, developing each season and then dropping off. The horns on the other hand are usually present in both sexes and as a rule are permanent throughout adult life. The short horns on the head of the giraffe are non-deciduous, and resemble the antlers of the deer in that they are true bony structures, but are always covered by the skin. The giraffe

FIG. 374. *Ovibos moschatus*, the barren ground musk ox, found only in arctic Am[illegible]
(From a photograph provided by the American Museum of Natural History.)

is a native of Africa. Deer are found over the whole habitable world, except in Australia and Africa, and include a large number of species. A few are without antlers, like the musk deer of central Asia, but in the great majority they are well developed. Here belong the various species of true deer, such as the axis deer of India, the red deer of Europe, the wapiti or American elk of Canada and the northwestern United States, and the Virginia deer, the Mexican deer, and the mule deer, — all three found in this country, — as well as several species living in South America, and also the reindeer and moose (Fig. 374), or elk as

it is called in Europe. The family having bony horns covered with a chitinous layer contains more species than any other family of Ungulata. It includes the domestic cattle, the ox, *Bos taurus*, the sheep, *Ovis aries*, the goat, *Capra hircus*, the African gazelle, the Indian antelope, the chamois of the Alps and the Pyrenees, the pronghorn antelope of the western United States, remarkable for the deciduous outer sheath of its horns and for its fleetness, — it is said to be the swiftest American game, — the bison, the buffalo, and very many other species (Fig. 374).

### Suborder 3. Proboscidea

The Proboscidea (Gr. *προβοσκίς*, proboscis), or elephants (Fig. 375), are strikingly different in general external appearance from the other Ungulata. They are provided with five digits on each

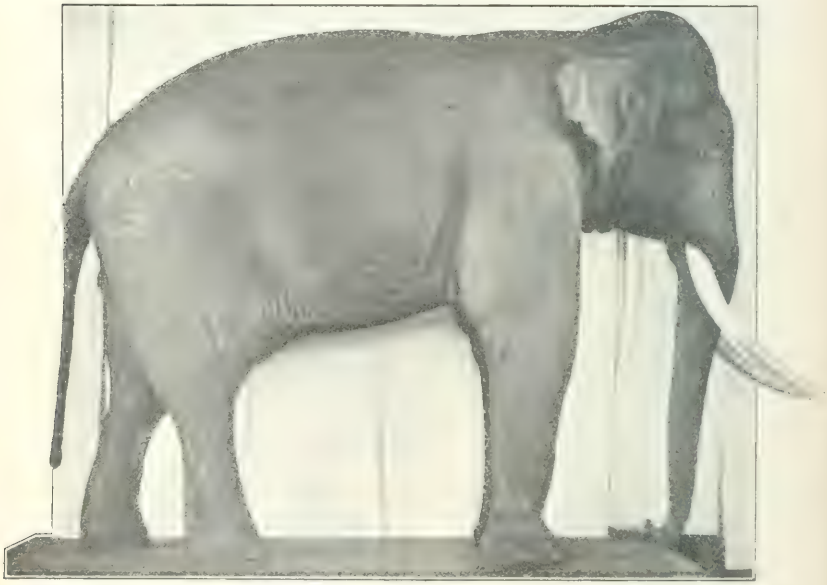


FIG. 375. *Elephas indicus*, the Asiatic elephant. (From a photograph provided by the American Museum of Natural History.)

foot, internally, but only three or four have external hoofs. The body is covered with a loose, thick, wrinkled skin, sparsely covered with hairs; the head is large and the snout greatly elongated to form a muscular proboscis, at the tip of which are the

nasal openings. The eyes are small, the external ears very large; the mammary glands, provided with two teats, are pectoral in position, and there is no scrotum; the tail is small. The tusks are greatly developed incisors; canine teeth are absent. There are only two species of living elephants, the Indian, *Elephas indicus*, and the African, *Elephas africanus*. The latter is the larger, though rarely over three meters high at the shoulder; it is darker in color than the Asiatic species, the external ears are much larger, and the tusks grow to a great size in both sexes, while in the elephant from India the tusks of the male are much larger than those of the female.

The extinct mammoths belonged to the same genus as the existing elephants; their remains have been found in Europe, northern Asia, and in North America as far south as Oregon. At the end of the eighteenth century one was found frozen near the mouth of the river Lena in Siberia; it was covered with hair twenty-five centimeters long on its body, and had a mane three times as long. There are several species of the huge fossil mastodons, remains of which have been found in Africa, India, Europe, and North and South America; some of them were the largest land animals that ever existed. On the other hand, there have been obtained from the island of Malta large numbers of remains of pygmy elephants no larger than sheep.

### Suborder 4. Hyracoidea

The Hyracoidea (Gr. ὕραξ, a mouse, and εἶδος, form) are represented by several species of a single genus, Hyrax (Fig. 376). There has been considerable difference of opinion concerning their position in the system of classification, but they are now very generally placed next the elephants. They are little animals about the size of rabbits, covered with brownish fur; the tail is very rudimentary. They have four toes on the front feet and three on the hind. Hyrax lives in

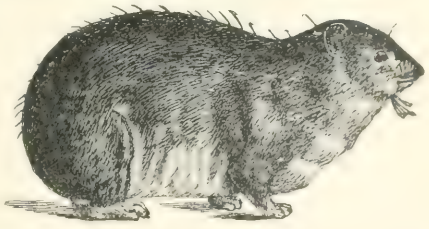


FIG. 376. *Hyrax syriacus*. (From Claus and Sedgwick's Text-book.)

cavities in rocks and trees in Africa, Arabia, and Syria, and is believed to be the "cony" referred to in the Old Testament.

### Order 5. Rodentia

The Rodentia (Lat. *rodere*, to gnaw), or gnawing mammals, constitute a sharply defined group of small animals, which may readily be distinguished by the incisor teeth; these are long, never more than two in the lower jaw, and in most cases only two in the upper jaw. Although they are continually being worn away at their free ends, the length remains constant, since they grow continually at the root. Canine teeth are always absent and, except in the hares and their immediate relations, the premolars are likewise usually lacking; thus there is a long toothless interval, or *diastema*, between the incisors and the molars. The food consists chiefly of seeds, fruits, roots, and stalks of plants. The toes are provided with claws, and there are usually five digits. The body is covered with soft fur in most of the Rodentia, sometimes with stiff contour hairs as well; in some the hairs are scanty and bristlelike, and in others some of the hairs may be modified into stiff spines or "quills." The testes may lie in the abdomen or in a scrotum, and the teats vary from two to ten; the uterus is two-horned.

As a rule the rodents are very prolific, producing several young at a birth, and some species have from four to six litters a year. Many build nests or burrows, and some lay up food in large quantities for the winter months; the latter generally have cheek pouches in which the food may be carried to the nest. Some rodents pass into an interrupted or a continuous winter sleep, and others migrate in large numbers. There are numerous fossils, some larger than any existing species. The order is a large one, containing some nine hundred living species, which may be grouped under four types represented by the squirrel, the rat, the porcupine, and the rabbit. Thus we have four suborders, under which we may best consider some of the more important representatives.

#### Suborder 1. Sciuromorpha

The Sciuromorpha (Lat. *sciurus*, squirrel, and Gr. *μορφή*, form), or squirrel-like rodents, include some animals which

superficially do not greatly resemble the squirrels. One of these is the beaver, *Castor fiber* (Fig. 377), the largest representative of this suborder; it is about sixty centimeters long, exclusive of the tail, which is about twenty-five. The body is covered with

FIG. 377. *Castor fiber*, the beaver. (From a photograph provided by the American Museum of Natural History.)

soft fur, which is well known because of its commercial value; it is absent on the tail, which is broad, scaly, and flattened dorsoventrally. The beaver is capable of felling large trees, of damming streams, and of building houses for itself; it feeds

FIG. 378. 1, *Sciurus carolinensis leucotis*, the common gray squirrel, black variety; specimen from Pennsylvania. 2, *Sciurus carolinensis extimus*, the everglade gray squirrel; specimen from Florida. 3, *Sciurus carolinensis leucotis*, the common gray squirrel of the United States; specimen from New York. (From a photograph provided by the American Museum of Natural History.)

chiefly on the twigs of the trees which it fells. At one time it was very generally distributed throughout the wooded regions of the entire northern hemisphere, but it has been so extensively hunted for its fur that it has been exterminated in many places.

The squirrel family proper includes ground animals and arboreal animals, all of which have the tails covered with fur. Of the former the largest are the woodchucks of the United States and Canada, sixty centimeters in length; the species found in Europe and Asia are called marmots. There are several species of marmots in the United States, the most familiar being the prairie dogs, whose burrows are so common in barren regions of the West. They are about a third of a

FIG. 379. *Anomalurus fulgens*, the African flying squirrel. (From Shipley and MacBride's Zoölogy.)

meter long, with a short tail of four or five centimeters, and live in large colonies; the story of the owl and the rattlesnake living peaceably in the same burrow with the prairie dog is an interesting fable. More squirrel-like in general appearance are the chipmunks, which are handsomely striped longitudinally, and provided with large cheek pouches for carrying food. The true squirrels (Fig. 378), with their bushy tails, are abundant over the whole inhabitable world except Australia. Every one is familiar with the red squirrels and the gray squirrels, of which

there are several species in the United States, where the large fox squirrels are also numerous. There is a very pretty little species of flying squirrel in North America, *Sciuropterus volucella*, with a body about fifteen centimeters in length and a broad, flattened tail equally long, and with folds of the skin between its anterior and posterior appendages. Very different in general appearance is the huge flying squirrel of Asia with its cylindrical tail, the body and the tail being each about sixty centimeters long. A similar squirrel lives in Africa (Fig. 379).

### Suborder 2. Myomorpha

The Myomorpha (Gr. μῦς, a mouse, and μορφή, form), rat- or mouse-like rodents, are mostly small animals. Some of the curious African species have the hind legs greatly developed, as in the kangaroo, and use them for taking enormous leaps; the largest of these is the so-called jumping hare of South Africa, about as large as a hare; the jerboas found in other parts of Africa resemble them except in size — they are only from fifteen to eighteen centimeters long. Very different in habits are the burrowing gophers, which are abundant in certain regions in North and Central America; they live almost entirely underground. The average size is about that of the house rat, but some are larger and others smaller. The pouched gopher of the Mississippi Valley is a great pest to the farmers. The muskrat is one of the largest members of this suborder. It inhabits North America and has a handsome fur, which has a considerable commercial value. The lemmings, which inhabit the arctic regions of the northern hemisphere, are interesting because of the migrations which they make in large numbers.

The genus Mus, with scaly tail, includes about a hundred species, and amongst them all the common rats and mice. Here belong the common brown rat, *Mus decumanus*, an omnivorous beast, and the common house mouse, *Mus musculus*; some of the other species are known by such popular names as wood mouse, field mouse, deer mouse, golden mouse, mole mouse, rice field mouse. Resembling some of these are the voles of Europe, placed in another genus. The wood rats of the United States also belong to another genus; one species living in the

West is eaten by the Indians, and has the reputation of being a great thief, carrying off all sorts of useless objects. Some interesting members of this group are confined to Europe, Asia, and Africa; among these are the hamsters, which have highly developed cheek pouches, and the minute dormice, only about seven centimeters long, with a tail like a squirrel's; both of these hibernate during the winter.

### Suborder 3. Hystricomorpha

The Hystricomorpha (Gr. *ὕστριξ*, porcupine, and *μορφή*, form), or porcupine-like rodents, comprise animals which differ very widely in external appearance. The majority inhabit the western hemisphere, and South America contains the largest number. To this group belongs the largest living rodent, the water cavy or capybara, which inhabits South America, especially Brazil; it is sometimes called the water pig because of its general shape and the fact that it takes so readily to the water. The body is about a meter and a quarter long, half a meter high, and is covered with coarse hair; the tail is very rudimentary. Perhaps next in size is the Patagonian cavy, from seventy-five to ninety centimeters long and thirty high. The little guinea pigs, of which there are several species, are confined to South America. One of the most common, *Cavia cobaya*, is often domesticated, and is extremely prolific. It is born with its permanent teeth, the milk dentition disappearing during fetal life. Economically the most valuable members of this group are the chinchillas, varying in length from twenty-five to thirty-five centimeters, with a tail about half as long; their soft silver-gray fur is familiar to every one; they live in Peru, Bolivia, and Chile.

Very different from these in general appearance are the porcupines, which have some of the hairs modified into stiff spines or "quills," barbed at the end in many species. The American species are more or less arboreal in habit, with thick fur and relatively short quills; those inhabiting North America are the larger and average about three quarters of a meter in length. The tail is the principal weapon of defense and is manipulated with great speed and skill. That porcupines can

project their quills is another zoological fable. The European porcupine (Fig. 380) is a terrestrial animal. One other member of this group should be mentioned, the coypu of South America,

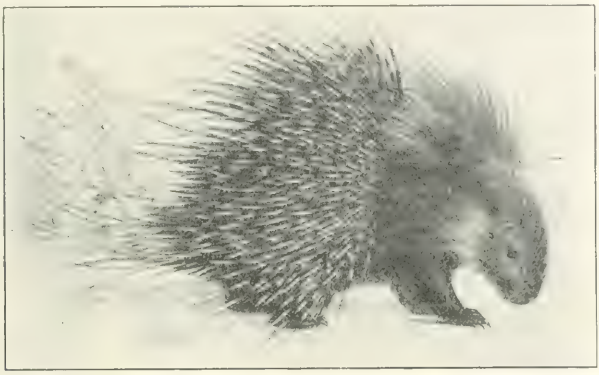


FIG. 380. *Hystrix cristata*, the European porcupine. (From Brehm's Thierleben.)

which is about the size of a beaver, but has a cylindrical tail. Its brown fur is soft and dense, and is known commercially as nutria. Some fossil Hystricomorpha found in South America were as large as oxen and were the largest known rodents.

### Suborder 4. Lagomorpha

The Lagomorpha (Gr. λαγώς, hare, and μορφή, form) are hare-like rodents (Fig. 381), which have one or two very apparent differences from the other suborders. They have four incisors in the upper jaw, and the testes lie permanently in a scrotum. The upper lip is always cleft on the median line. The skin is very thin and covered with a soft, woolly fur, which in many hares wholly or partially whitens in winter. The hares and rabbits belong

FIG. 381. *Lepus sylvaticus*, the wood hare of the United States. (From a photograph provided by the American Museum of Natural History.)

to the genus Lepus; the common hare of Europe is *Lepus timidus;* the most common rabbit in the United States is *Lepus sylvaticus*, the wood rabbit or Molly cottontail, which is our nearest relative to the European rabbit, *Lepus cuniculus*. The most common distinction made between the rabbits and the hares is that the former burrow and the latter do not. In the western United States we have several interesting species, known popularly as jackass hares or jack rabbits; their speed is truly marvelous. Related to the rabbits are the pikas, about eighteen centimeters long, with almost no tail at all. They are found in the mountains of Asia, Europe, and western North America; here they are popularly called conies.

### Order 6. Insectivora

The Insectivora (Lat. *insectum*, insect, and *vorare*, to devour) are small mammals, usually having five toes to the feet, armed with claws, resembling some of the rodents in general external appearance, but readily distinguished from them by the dentition, which here is complete, all four kinds of teeth being present. The permanent teeth appear early, so that the milk teeth are rarely functional. The body is usually covered with soft fur, but in some sharp spines develop also. The testes are always internal. A very characteristic feature of the Insectivora is the snout or muzzle, which is always more or less elongated and extends much farther forward than the lower jaw. The eyes are generally small and in some species almost entirely concealed by the fur. They are mostly nocturnal in habit; some burrow in the ground, a few are amphibious or aquatic, and some are arboreal. They all feed on insects and other small animals such as worms, and are widely distributed, being unknown only in South America and Australia.

The largest member of the order is found in equatorial Africa. It measures about thirty centimeters in length, with a tail almost equally long; the tail is laterally compressed and serves as an efficient organ for swimming, as the species is amphibious. The moles, which are found in the temperate regions of the eastern hemisphere and North America, have the paws well adapted to digging, and make very elaborate and extensive

passages and chambers underground; in consequence, they cause considerable annoyance to the farmer in Europe. The tail is generally short, and the body is covered with soft, dense fur. In the United States and Canada one of the commonest species is the star-nosed mole, with a circle of radiating projections about the tip of the snout; it is found from the Atlantic to the Pacific. The shrews are found throughout the northern hemisphere; some species, both in the United States and in Europe, are aquatic. The ciliated shrew, which inhabits the countries bordering the Mediterranean, is of interest because it is said to be the smallest living mammal; the body measures about four and a half centimeters in length, and the tail about two. The hedgehogs (Fig. 382) are confined to Europe and Asia, where they are abundant.

FIG. 382. *Erinaceus europæus*, the hedgehog. (From Brehm's Thierleben.)

The common European species is about twenty centimeters long and relatively broad; the dorsal surface is provided with numerous short, stout spines, and when alarmed it rolls itself into a ball, with the spines projecting in all directions. It passes the winter in a deep, unbroken sleep in a hole or hollow tree, living on its stored-up fat.

Africa possesses two or three curious species of Insectivora, such as the jumping shrews, whose elongated hind legs recall the kangaroo again; the elephant shrew, with a body ten to twelve centimeters long, whose elongated snout recalls the trunk of the elephant; and the golden moles, whose hair exhibits brilliant metallic colors. There is a curious animal, the colugo, or galago, *Galeopithecus volans* (Fig. 383), living in the East Indies, which some zoölogists place in this order; it has a broad membrane extending between the anterior and posterior extremi-

ties and from the hind legs to the tail, so that it can sail through the air for a considerable distance from tree to tree, much as the

FIG. 383. *Galeopithecus volans*, the colugo. (After Vogt and Sprecht, from Parker and Haswell's Text-book.)

flying squirrels do. There are many points in its anatomy which differ from the typical Insectivora, and some scientists place it in the order of Primates, to be considered later.

### Order 7. Chiroptera

The Chiroptera (Gr. χείρ, hand, and πτερόν, wing), or bats (Fig. 384), are the flying mammals, and most of them are practically incapable of any other kind of locomotion. The wings are delicate membranes, soft and silky, which extend from the anterior to the posterior appendage, and between the two posterior limbs, this last membrane being called the interfemoral. All the digits of the anterior appendages except the first are greatly elongated to form a support for the wings. The first

digit of the fore limb is tipped with a claw, and in some bats there is a claw on the second digit as well. All five digits of the hind foot are clawed. The body is usually covered with short, soft fur, except in one group, which is practically naked. There are two mammæ on the thorax, and in some species these are thought to be functional in the male as well as in the female; the penis is pendant, and there is no scrotum. The dentition is complete. All the special sense organs except sight are highly developed, especially the sense of touch. Of the internal anatomy we need merely note that the bones are very light, and a keel is developed on the sternum for the attachment of the pectoral muscles used in flight, very much like that found in birds. Many of them have a strong, musky odor, due to the

FIG. 384. *Synotus barbastellus*, a bat. (After Vogt and Sprecht, from Parker and Haswell's Manual.)

secretion of certain glands in the skin. The bats are nocturnal animals, generally gregarious, but the sexes live apart, as a rule, except during the breeding season; during the daytime they remain in dark places, suspended by their claws, head downward (Fig. 385). Many of them hibernate during the winter months. They feed chiefly on insects; some live entirely on fruits, and others suck the blood of warm-blooded animals. Fossils are rare in this order.

The bats comprise over four hundred species, and may be separated into two groups. In the one belong the majority of the larger bats, some seventy species; they feed exclusively on fruits and have claws on both the first and second digits of the fore limb. The tail, when present, is not included in the interfemoral membrane, but lies below it. These bats, known

popularly as flying foxes, live in the tropical forests of Africa, the East Indies, and Australia; the expanded wings of the largest species measure a meter and a half from tip to tip. The snout is elongated like that of a fox, and never has leaflike

FIG. 385. *Xantharpyia collaris*, an African bat; female and young. (From Shipley and MacBride's Zoölogy.)

appendages such as are found in some others. Many species are eaten by man. Some members of this group are known to devour much more food than they can assimilate, eating apparently for the mere pleasure of doing so.

The second group of bats, often called the smaller bats, as the average size is less than in the preceding, have the tail when present included in the interfemoral membrane, and only one claw on the fore limb, that being on the first digit. They are for the most part insectivorous, but some feed upon fruits. These bats are very widely distributed over the world, being most abundant in the tropics, while some occur in temperate regions. Some have curious leaflike outgrowths of the skin on the snout, sensory in function, and naked like the wings. Such bats are called nose-leafed. The snout is always short, not elongated, as in the flying foxes. There are two small bats which are very common in the eastern United States: the red bat, *Atalapha noveboracensis*; and the brown bat, *Vespertilio subulatus*; other species of this latter genus have a wide distribution from the Atlantic to the Pacific. It is in the tropics, however, that the greatest variations in shape and size occur. In Brazil is found the false vampire bat, *Vampyrus spectrum*, incorrectly reputed to be a bloodsucker, — it feeds exclusively on fruits. There are bats, however, which suck the blood of birds and mammals, and so are true vampires. One of these, *Desmodus rufus*, is found in Brazil, Chile, and northward into Mexico; Darwin reports it as biting horses.

## Order 8. Carnivora

The Carnivora (Lat. *carnivorus*, flesh-eating, from *caro*, flesh, and *vorare*, to eat) may be called the beasts of prey; they include the boldest and fiercest mammals, of quick intelligence, and with the organs of special sense very keen as a rule. As their name implies, they feed chiefly on other animals, although some are to a considerable extent vegetarians. The body usually has a thick covering of hair or fur; the feet are four- or five-toed, and the digits are armed with sharp claws in most instances. The mammæ are abdominal in position; the testes lie in a scrotum in the terrestrial Carnivora, internally in the aquatic. All four kinds of teeth are present as a rule; the incisors are small, and the canines are well-developed, strong, pointed, and more or less recurved; the remaining teeth are adapted for cutting rather than grinding. The milk dentition

is generally functional for about a year. The Carnivora are found all over the world, although individual species may have a very restricted distribution. The living representatives of this group are readily separable into two suborders.

### Suborder 1. Fissipedia

The Fissipedia (Lat. *fissus*, cleft, and *pes*, foot), sometimes called the *Carnivora vera*, are for the most part terrestrial in habit and comprise the bears, dogs, and cats with their respective relatives. The raccoons, of which there are several species, may be noticed first. Our common raccoon, *Procyon lotor*, is widely distributed throughout the United States. The body is covered with a soft, short fur and longer hairs, gray mixed with black, and the tail is ringed. When full grown the animal may measure ninety centimeters from tip of nose to tip of tail, — the latter is about a third of the total length. It partially hibernates in our colder states. The Mexican raccoon is found in Mexico and the southwestern portions of the United States. Another species is confined to South America, where the closely related coatis are also found; the latter are represented in Central America and Mexico as well.

The true bears belong to the family Ursidæ; they have as a rule a mixed diet, feeding on fruits, vegetables, honey, and insects, but the polar bear is entirely carnivorous. One of the most widely distributed is the brown bear, *Ursus arctos*, which lives in Europe, northern Asia, and Arctic portions of North America; it may attain a length of nearly two meters, although the average length is less; in cold countries it hibernates. This species is capable of being tamed and trained to a certain extent, and is the common performing bear. The bear of the Bible is the Syrian bear, *Ursus syriacus*, still found in Palestine. The black bear, *Ursus americanus*, is confined to North America. It is usually a vegetarian, hibernates in hollow trees or caves, and weighs from one hundred to two hundred kilos; the cinnamon bear of the Rockies is a variety of this species. The grizzly bear, *Ursus horribilis*, is found in the Rockies and the plains to the eastward; it is the most formidable of bears, and attains a length of about two and three quarters meters, and a weight of

nearly four hundred kilos. The polar bear is confined to the Arctic zone; its hair is creamy white, the claws black. It may attain a length of two and a half meters or even more; its food consists chiefly of fishes and seals, and it is the only bear of aquatic habits.

Related to the bears are several kinds of smaller Carnivora, many of which are of considerable economic importance because of their valuable fur. The otters have webbed feet, adapted to their aquatic habits. The sea otter is found off the coast of Alaska; it attains a length of a little over a meter, is extremely shy, and is difficult to catch. The true otters are represented by a species in Brazil, another in Mexico, the common American otter, ranging over the whole temperate zone of North America, — it is one of the largest species, — and the common otter of Europe. This last species is sometimes trained to fish, and the practice is common in India and China as well. The skunks are found in North and South America and are most familiar because of the abundant secretion of their anal glands. The common North American species, *Mephitis mephitica*, can eject this secretion for a distance of two and a half or three meters, and the odor is so penetrating that it may be perceived at a distance of over a kilometer and a half; they are slow-moving animals and partially hibernate. The badger is common in Europe and Asia. The badger of North America is placed in another genus; it is abundant west of the Mississippi, feeds upon small rodents such as gophers, and has a broad, flat body, about sixty centimeters long. All the badgers are good burrowing animals. In connection with the foregoing should be mentioned the minks, and the several related species of the same genus, such as the ferrets, the weasels, and the stoat, or ermine. The European ferret, or polecat, is found in Asia as well as Europe. In America we have the black-footed ferret, while the true ferret is a native of Africa and is a permanent albino, with white fur and pink eyes; they are valuable as ratters. There appears to be only a single species of ermine, *Putorius ermineus*, which extends northward as far as any terrestrial mammal; it is found in Europe and Asia, and in North America as far as our Southern states. In summer its fur is reddish brown in color, in winter a pure white except the black tip of the tail. It kills

large quantities of rats and mice, often for the mere pleasure of killing. The odor of the secretion from its anal glands is very much like that of the skunk, but is not so lasting. Finally, we may notice the sables, or martens; the names are generally used interchangeably. The American sable, or pine marten, is about the size of a house cat, but has rather shorter legs. The Asiatic sable, *Mustela zibellina*, lives in the coldest portions of Siberia and Russia; it furnishes the most costly of furs, and as the animals are taken in the winter months, the hunters often suffer greatly from the intense cold.

FIG. 386. *Vulpes azaræ*, a Brazilian fox. (From Brehm's Thierleben.)

The next group of Carnivora consists of the doglike mammals; they as well as the cats walk on their toes instead of on the whole sole of the foot as the bears do. These two methods of walking are spoken of as digitigrade and plantigrade respectively; the terms are not restricted to the Carnivora, but may be applied to any of the Mammalia. The doglike Carnivora generally have five toes on each of the front feet and four on the hind, and the toes are armed with claws which are not retractile. The foxes may be distinguished from the true dogs and the wolves by their bushy tails and their more elongated muzzles. Foxes are found in Europe, Asia, Africa, and North and South America (Fig. 386). Our common red fox, *Vulpes fulvus*, varies much in color, even to the extent of being gray or even black;

it ranges from Georgia northward, and westward to the Rockies. It measures about a meter and a quarter from tip to tip, but the tail is rather more than a third of the total length. It resembles much the European fox, *Vulpes vulpes*. The gray fox has a range throughout the United States, but is becoming scarce and giving way to the red fox. One of the smallest and prettiest of the foxes is the Arctic fox, which lives in the Arctic regions of both continents; the fur is soft and silky, a bluish or brownish gray in summer and pure white in winter.

There are several varieties of the wolf, *Canis lupus*, which is found in Europe, Asia, and America. They are the largest and

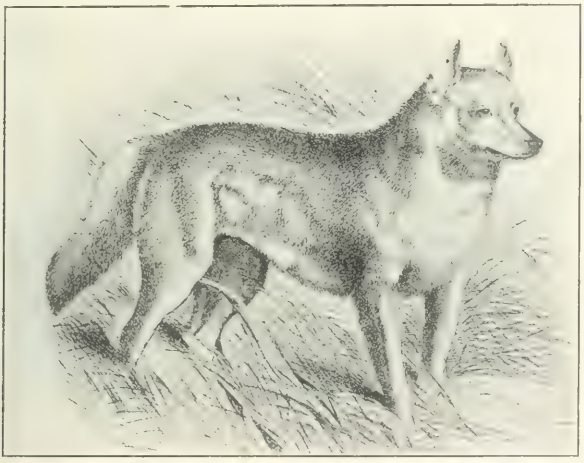


FIG. 387. *Canis dingo*, the dingo dog of Australia. (From Brehm's Thierleben.)

fiercest of the doglike types and hunt in packs; the prevailing color is gray, but there is great variation, and some are black, others reddish, others a yellowish white. The American wolf is generally smaller than the European. In South America are found the fox wolves, which are wolflike in general appearance, but have bushy tails like a fox. The coyote is smaller than the wolf and more timid, and corresponds in America to the jackal of Asia and Africa. The dingo dog, *Canis dingo* (Fig. 387), is believed to be the only native representative of the Carnivora in Australia. The domestic dog, *Canis familiaris*, has probably descended from several wild species and has often inter-

bred with the fox, the wolf, the jackal, and other species. It has always been domesticated as far back as we have the history of man. In Asia there are several species of wild dogs which closely resemble jackals. There are two species of hairless dogs known, both from South America (Fig. 388).

The catlike Carnivora include the hyenas, the civet cats, and the true cats, all almost strictly carnivorous in habit. The hyenas are cowardly animals, hunting at night, but with very powerful jaws, which can crush the hardest bones. There are only three living species, two of which are large, varying from a meter to a meter and a quarter in length. The striped hyena,

FIG. 388. A hairless dog. (From a photograph provided by the American Museum of Natural History.)

one of the largest, is found over all Africa, while the small brown hyena is a native of Cape Colony. The family of the civet cats is confined to the eastern hemisphere, the majority living in Asia and Africa. Their claws are partially retractile; the family contains many genera and species. The anal glands of the true civet cats give rise to a secretion which can be removed from the living animal, and is much used as a perfume in many Asiatic countries; the lesser civet cat is called the rasse, and its scent is in great favor with the Javanese, who completely impregnate their clothing and their houses with it; to the European and American the odor is not entirely agree-

able. One or two related animals may be noticed, such as the ichneumon, or Pharaoh's rat, of Egypt and northern Africa, a valuable animal which feeds on crocodile eggs as well as snakes, lizards, and rats; and the mongoose of India, which kills large serpents and other venomous animals, and is consequently kept in a state of semi-domestication.

The members of the Felidæ, or cat family, have five digits in front and four behind, and the toes are armed with sharp, curved claws which can be completely retracted between folds of the skin, while the animal walks on the soft pads beneath. The body and tail are covered with a more or less soft, thick fur; the tail is long, the face broad and short and never with an elongated muzzle as in the dogs. While most of the cats are terrestrial, some are arboreal, and nearly all have an intense dislike for the water. There are some fifty species, which are found in Europe, Asia, Africa, and North and South America; the majority belong to Asia. The largest existing cat is the tiger, *Felis tigris*, which may attain a length of three and a third meters, exclusive of the tail; it is tawny yellow in color with black stripes about the body and a ringed tail; it is most abundant in southern Asia but extends northward through China and even into southern Siberia. The lion, *Felis leo*, is neither as large nor as strong as the tiger; a full-grown male is scarcely three meters in length without the tail, and weighs about three hundred kilos; they are said to live to an age of thirty or forty years. The lion is found throughout Africa, and in Asia in the southwestern countries as far east as western Hindustan. The color of the hair is generally a yellowish brown. The male is larger than the female and has a mane on the neck and head, sometimes dark or even black in color; the tail in both sexes is tipped with a black tuft of hairs.

The leopard, or panther, *Felis pardus*, is likewise confined to the eastern hemisphere; the head and body are but little over a meter in length, and the tail is nearly as long. The color is usually yellowish, with dark spots more or less grouped in rosettes. It is arboreal in habit and occurs throughout Africa, the whole of southern Asia as far as northern China and Japan, and also in some of the East Indies. The puma, *Felis concolor*, is found in North and South America, except in the colder por-

tions, and is known by a variety of popular names, such as American lion, catamount, panther, and painter. It is generally a reddish brown in color, without markings, and may attain a length of nearly a meter and a half to the root of the tail. The largest and strongest American cat is the jaguar, which ranges over the whole of South America except the colder regions and as far northward as Texas. It is spotted like the leopard, but with larger spots; there is great variation in the colors. In size and strength it is surpassed by only the tiger and the lion. It feeds on the large rodent, capybara, common in South America, and on peccaries. It is said to be fond of monkeys, but they are difficult to secure because of their agility.

The true wild cat, *Felis catus*, belongs to Europe and western Asia. It is probably not the ancestor of our domestic cat, *Felis domestica*, which is believed to be descended from the domestic cat of Egypt, which was mentioned in inscriptions as early as 2000 B.C., and was even embalmed. There are many varieties of the common cat, some of the more curious being the angora, or Persian cat, and the tailless cats of the Crimea and of the Isle of Man; the latter is commonly called the Manx cat, as it appears to be a native of the island. Many species of wild cats occur in Asia, and several are known from Africa. In America we have the ocelot, a handsome spotted cat, extending from Patagonia to Arkansas; it is about seventy-five centimeters to the root of its tail, and the tail itself is about half that length. The lynxes of Europe and America may all be classified as varieties of a single species, *Felis borealis;* the tufts of hairs on the tips of the ears readily distinguish it. In Mexico and Southern California we find the spotted lynx; throughout the United States is the red lynx; and northward the Canadian lynx, often called *Lynx canadensis*. Other varieties occur in Europe, Asia, and Africa.

### Suborder 2. Pinnipedia

The Pinnipedia (Lat. *pinna*, fin, and *pes*, foot) are aquatic Carnivora; the body is more or less fishlike but covered with hair or with fur; the tail is extremely short, and the toes are united so that the feet become paddle-like and are not adapted to extensive locomotion on land; just beneath the skin is a

relatively thick layer of fat. They may be divided into two groups, the first comprising the walruses and the seals which have ears, and the second the earless or true seals.

The walruses have no external ears, and there is no free tail; the upper lip is provided with a fringe of stiff bristles, and the body is covered with short, yellowish brown hairs. The canine teeth in the upper jaw are elongated into large tusks, and these, together with the hide and oil, are articles of commerce. An adult male walrus is between three and a half and four meters long. Their food is said to consist chiefly of Mollusca and seaweeds. There are two species of walruses, one in the Atlantic, the other in the Pacific. The eared seals, unlike the walruses, have no tusks; there are two kinds, the sea lions, or hair seals,

FIG. 389. *Phoca vitulina*, the harbor seal. (After Parker and Haswell.)

and the sea bears, or fur seals. Both occur along the coasts in the northern and the southern hemispheres in temperate and cold waters, except in the North Atlantic, where they are absent. The northern sea lion of the North Pacific is one of the largest. They are gregarious and polygamous, each male having from twelve to fifteen or more females. The most valuable fur seal is *Callorhinus ursinus*, the northern fur seal; it has a nearly black, silky under fur. The male is about two meters in length, the female less.

The earless or true seals have a shorter neck than the others, and their appendages are not so well adapted to supporting the body on land. They have no soft fur, but only stiff hairs. The harbor seal, *Phoca vitulina* (Fig. 389), is the common seal of the North Atlantic; it is found also in the Mediterranean and in

the North Pacific; it attains a length of about a meter and three quarters. This species lives near the shores, and may even ascend rivers for long distances; it lives chiefly on fish. There are several other species, varying in size and distribution. One of the largest is the sea elephant, found in various places off the western coast of North and South America; it averages about four meters in length, but one is on record which measured six meters. The male has the snout elongated into a proboscis, about thirty-five centimeters long, and it can be still more elongated under excitement. The female has no proboscis and is smaller than the male.

### Order 9. Primates

The Primates (Lat. *primus*, first) stand at the head of the animal kingdom and include the apes, the apelike mammals, and man. They are pentadactyl, and have the innermost digit opposable to the others except on the anterior appendages of some monkeys and on the posterior extremities in man. The digits are usually provided with flattened nails, rarely with claws. There are almost always two pectoral mammæ, sometimes there are two on the abdomen; and the testes lie in a scrotum. The eyes are directed forward, the dentition is heterodont. Almost all the Primates are adapted to an arboreal life. They are readily divisible into two suborders.

#### Suborder 1. Lemuroidea

The Lemuroidea (Lat. *lemuris*, ghost, and Gr. εἶδος, form), or lemurs (Fig. 390), are small animals varying in size from a mouse to a fox, which live on the island of Madagascar, the adjacent parts of the African continent, and on the islands of the Indian archipelago. They are arboreal in habit and mostly nocturnal, often living in large troops; many are capable of uttering very loud cries. They feed on dates and other fruits, as well as on insects and the blood of small birds. Some species are very curious and grotesque in appearance, such as the specter, *Tarsius spectrum*, found in Borneo and Sumatra, which has very large eyes; the body is about thirty centimeters long, the tail somewhat longer. The aye-aye, *Chiromys madagascarensis*, a native

of Madagascar, is covered with brownish black hair; its body and tail are each about fifty centimeters long; it has large, projecting ears and very long fingers and toes, and, though an object of considerable veneration by the natives, does not appear to be

FIG. 390. *Lemur catta*, the ring-tailed lemur. (From Shipley and MacBride's Zoölogy.)

a very intelligent animal. Fossil Lemuroidea are not confined to the same regions as the living species, but are found in America and Europe, so that formerly the group had a much wider distribution. The Galeopithecus, already referred to under the Insectivora, is placed in this suborder by some zoölogists.

### Suborder 2. Anthropoidea

The Anthropoidea (Gr. ἄνθρωπος, man, and εἶδος, form) have the brain more highly developed than any other animals. The

two mammæ are always thoracic in position. All except man are confined to the warmer countries, and the majority are gregarious, being either arboreal or terrestrial. The smallest and most lowly developed are the squirrel-like marmosets, which are confined to the northern portion of South America, living more especially in Brazil. The body is from twenty to thirty centimeters long, and the tail, as long or longer, is never prehensile

FIG. 391. *Ateles*, a spider monkey. (From a photograph provided by the American Museum of Natural History.)

as it is in many monkeys. The hair is usually soft and varies much in color and length; it is often yellowish, reddish, or black and with more or less white. The digits are nearly all provided with claws instead of nails. They are chiefly insectivorous.

The remaining Anthropoidea, exclusive of man, are often spoken of as the New World monkeys and the Old World monkeys, the two groups taking their names from their habi-

tats, which are associated with structural differences as well. The former are also called the broad-nosed monkeys, since the nasal septum is so broad that the nostrils are directed outward rather than forward. The number and also the arrangement of the teeth is constant, and may be represented by the following dental formula, indicating the teeth in one half of each jaw: incisors $\frac{2}{2}$, canines $\frac{1}{1}$, premolars $\frac{3}{3}$, molars $\frac{3}{3}$. The tail is sometimes longer, sometimes shorter, than the body and is often very useful as a prehensile organ. The fur of some of these monkeys is soft and silky and has considerable commercial value; in other cases it is coarse. The flesh of many is eaten by the natives of South America. The largest of the New World monkeys is the black howler, whose body is some seventy centimeters long; all of the howlers have resonance chambers in the throat by means of which they produce their piercing cries. The spider monkeys (Fig. 391) are so called because of their slender bodies, long legs, and very long, prehensile tails; they are common in Brazil and Central America.

The Old World monkeys have a narrow nasal septum, so that the nostrils lie close together and are directed forward instead of outward. Their dental formula is constant, being incisors $\frac{2}{2}$, canines $\frac{1}{1}$, premolars $\frac{2}{2}$, molars $\frac{3}{3}$, which is the same as that of man. Their digits are always provided with nails, never with claws, and portions of the body are often destitute of hair the skin in such regions being brilliantly colored, often red, blue, or green. The tail may be long or entirely absent, and is never prehensile as in the New World monkeys. Further, their brain is more highly developed and they are usually larger. They live for the most part in tropical Africa and Asia. Here belongs the common baboon of Africa, *Cynocephalus babuin*, with a body a meter long and a tail half as long; another species of the same genus is the mandrill, whose tail is only about two centimeters long; the adult is very conspicuous, because of the bright red and blue skin on its fore and hind quarters. The macaques of India and the Pacific islands are, like many New World monkeys, common in menageries. Many species of small monkeys inhabit Africa and display the most varied colors; a striking example is the green monkey, whose coat is of an olive-green color.

The apes which stand highest in the scale of development are the gibbons, the orang-utang, the chimpanzee, and the gorilla. The gibbons live in southeastern Asia and adjacent islands; they have no tail, and their arms and legs are very

FIG. 392. *Simia satyrus*, the orang-utang, sitting in its nest. From a specimen in the Cambridge Museum, England. (From Shipley and MacBride's Zoölogy.)

long. In habit they are arboreal, social, and feed chiefly on fruits. The orang-utang, *Simia satyrus* (Fig. 392), sometimes called "the wild man of the woods," is found only in Borneo and Sumatra. The face, hands, and feet are naked, the rest of the body is sparsely covered with rather long, reddish brown

hair. The largest specimen measured is said to have been about one hundred and twenty-five centimeters high. *Troglodytes niger*, the chimpanzee (Fig. 393), is a native of western and central Africa; it is usually black in color and attains a height of about one hundred and fifty centimeters. The gorilla, *Troglodytes gorilla* (Fig. 394), is likewise a native of Africa; its hair is dark gray in color and it may exceed the height of the chimpanzee by fifteen or twenty centimeters. These three largest apes are all more or less arboreal, make nests for themselves in the branches, and feed chiefly on fruits and twigs. Which one most resembles man it is difficult to say. The orang has relatively longer arms than the other two, but its brain is apparently more highly developed.

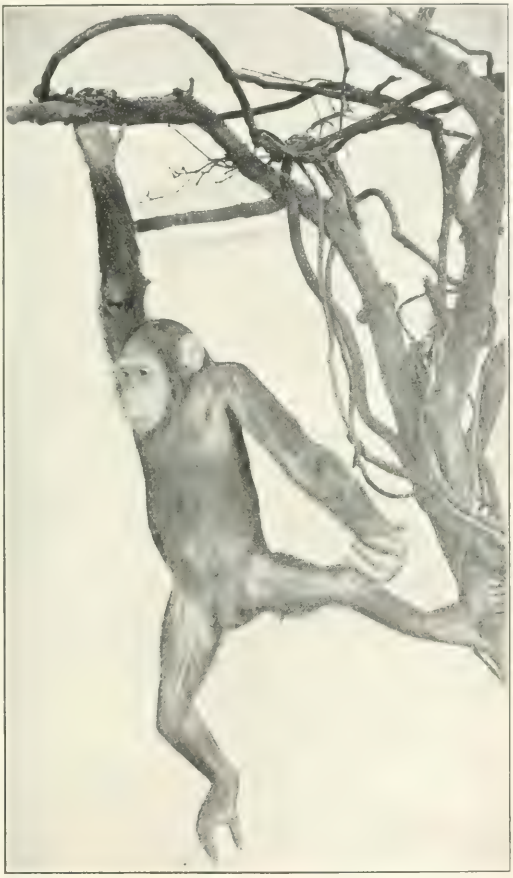


FIG. 393. *Simia troglodytes* or *Troglodytes niger*, the chimpanzee. (From a photograph provided by the American Museum of Natural History.)

Man, *Homo sapiens*, displays many points of resemblance to these anthropoid apes, but also several very fundamental differences. The arms are relatively shorter than in the apes, the thumb is longer and more mobile, the great toe cannot be approximated to the others. The hair is very unequally distributed over the body, the erect position is easiest

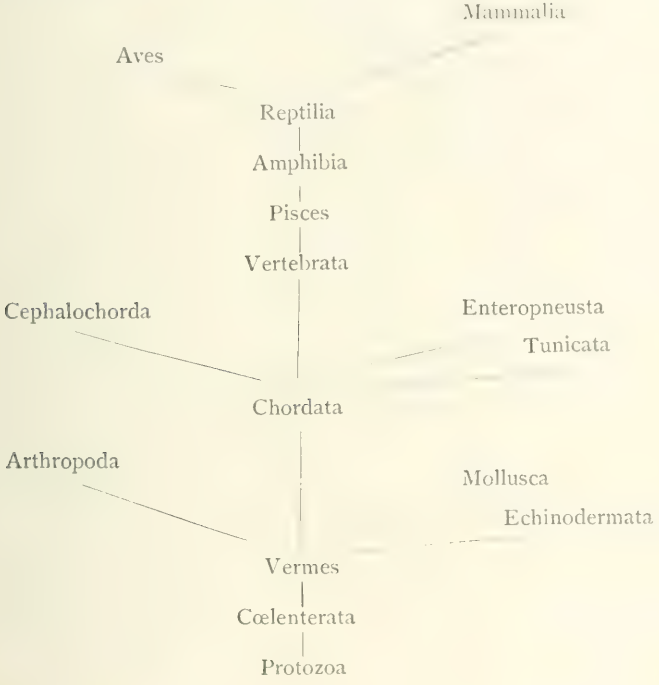
for locomotion, and articulate speech is found only in man. But the greatest difference lies in the enormous capacity of the human cranium and the corresponding great development of the brain. When, however, we take into account the variations in the size of the human brain which occur in adult individuals in different

FIG. 394. *Gorilla gina* or *Troglodytes gorilla*, the gorilla. (From a photograph provided by the American Museum of Natural History.)

races, and certain fossil crania which have been discovered, we find that the anatomical differences between man and the anthropoid apes are less than the differences between the anthropoid apes and the New World monkeys.

We have had occasion to refer from time to time to the relationship between different groups of animals; according to

the theory of evolution, which is described in a subsequent chapter, the higher animals have been evolved from the lower in the course of ages, but the groups existing to-day do not form a linear series from the lowest to the highest. The relationship is better expressed by a treelike arrangement, and the following diagram will illustrate the probable position of the various larger groups: —



# Part III

# THE GENERAL PRINCIPLES OF ZOÖLOGY

# CHAPTER X

## PREHISTORIC ANIMALS

We are tolerably familiar with the structure and habits of many animals which lived on the earth in prehistoric times; many of these have no living representatives, — they are extinct; others exist to-day almost identical in form with some which lived ages ago; still others have left descendants which have become modified from age to age until they are represented to-day by individuals very different from their earliest known ancestors, with which, however, they are connected by a series of links forming a complete chain. These animals are known to us through their fossil remains, the study of which constitutes the principal branch of the science of palæontology.

Although the number of fossils known is very large, they are far from giving us a complete picture of the animal life of the past, — in other words the palæontological record is necessarily very imperfect. There are several reasons for this. As we have already noted in Chapter II, it is usually only the hard parts of animals that are preserved as fossils, which therefore consist mostly of shells, bones, teeth, and other skeletal structures; there are occasionally, however, fossil remains of very soft animals, such as jellyfishes, for example. As a rule the soft parts are eaten by other animals or disintegrate and are washed away, retaining no trace of their original form. We noted further that fossils occur only in stratified rocks, which are formed for the most part under water by the slow deposition of material carried down by the rivers to the oceans, seas, and lakes. Hence aquatic animals are much more likely to be preserved as fossils than land or air animals, for the chances that the latter will become buried in such sedimentary deposits are relatively small. Thus our knowledge of prehistoric marine

life is the most complete of all. Again, the fossiliferous rocks which are readily accessible for investigation are relatively few; vast masses are still buried deeply beneath the water; those which form the dry land are exposed to a very small extent only, and we must often rely on excavations for roads and canals and similar constructions for bringing buried strata to light. Thus it will be at once apparent that only a very small number of the fossils which the earth contains are in the possession of man; great areas of the land have not been explored at all, and our knowledge of this subject will be vastly increased by future researches.

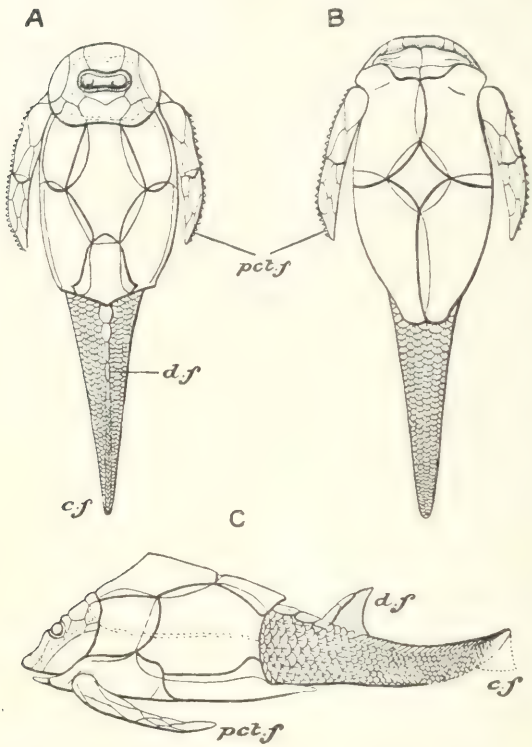



FIG. 395. *Pterichthys testudinarius.* A, dorsal aspect; B, ventral; C, lateral. *c.f*, caudal fin; *d.f*, dorsal fin; *pct.f*, pectoral fin. (From the Brit. Mus. Cat. of Fossil Fishes.)

It has been estimated that the stratified rocks constitute a mass which ranges from 60,000 to 90,000 meters thick. Of this two thirds, or from 40,000 to 60,000 meters, belong to the Archæan era, in which there are no fossils. The composition of these rocks shows us, however, that they once contained organic remains, but all the rocks of this group have become so altered that there is not the slightest evidence from the rocks themselves as to what the fossils were which they contained. Thus the first, the most important, and the longest chapter in the record of prehistoric life is absolutely closed, but much remains, and it

is of the greatest value in giving us a truer conception of the relationships of animals to one another. Concerning the period of time necessary for the formation of the sedimentary rocks we can conjecture only, for we do not know what the rate of deposition in the past may have been; the time, however, must in any case have been inconceivably great.

Our oldest fossils, then, come from the Cambrian rocks. Here we find remains from all the types of the animal kingdom except the Chordata, but the species are all marine, with the exception of some insects. These types are, furthermore, quite as sharply individualized as we find them in living animals to-day; that is to say, there are no intermediate species to form

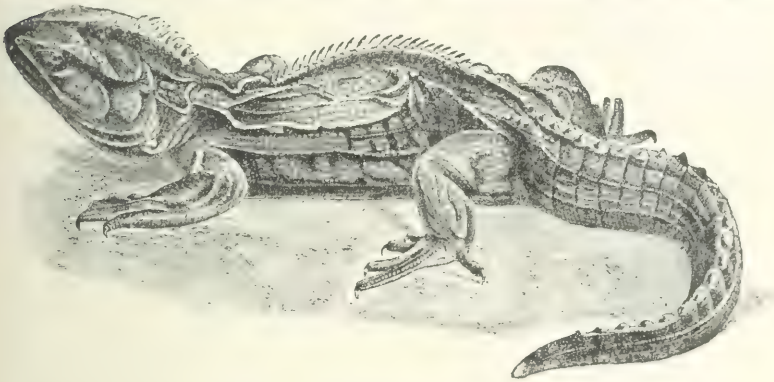


FIG. 396. *Hatteria punctata.* (After Brehm, from Parker and Haswell's Manual.)

a complete series of connecting links between them. This fact does not signify that each of these types was formed during that period as a group clearly differentiated from the others. As we have just noted, there was life on the earth before the Cambrian; furthermore, if representatives of the Chordata had existed at that period we know of no reason why they should not have left fossil remains. The range of animal life, then, in the Cambrian was much more limited than it is to-day, and this conclusion applies not only to the types but to their various subdivisions as well; thus many classes of invertebrates were not represented then at all.

In the next period, the Silurian, we find much the same groups as in the Cambrian, and in addition several new classes and orders of invertebrates as well as some fishes, notably

representatives of the Elasmobranchii and of a group now extinct, the Ostracodermi (Gr. *ὄστρακον*, shell, and *δέρμα*, skin) (Fig. 395), which had a well-developed skeleton on the outside of the body, but as far as we know no hard internal skeleton. The Ganoidei also appeared at this time. Thus this period introduced the vertebrates, but only through some of their more lowly organized representatives, while it contains no trace of any of the higher classes.

FIG. 397. *Cephalaspis lyellii*, much reduced. (After Günther, from Parker and Haswell's Manual.)

The Devonian period has often been called the age of fishes because of the abundance of their remains. The Ostracodermi and Ganoidei are numerous, and the Dipnoi first appear here; but there are no Teleostei until we reach a much later period. The Ganoidei attain their maximum development at this time; they have very few living representatives to-day. The most notable characteristic of all these fishes is the well-developed external skeleton, consisting largely of a veritable armor of very hard scales.

In the Carboniferous period, which is of great popular interest through its vast forests which gave rise to our deposits of coal, we find appearing, in addition to the animals of the preceding formations, Araneida, Myriapoda, and Insecta; here are found also the first remains of Amphibia belonging to an order now extinct, the Stegocephali (Gr. *στέγω*, to cover, and *κεφαλή*, head). They usually possessed two pairs of lateral appendages, a tail, and an external skeleton, a structure found in no living Amphibia; they were often of great size.

In the Permian, the last of the Palæozoic formations, are found the first remains of the Reptilia. There is a genus

Palæohatteria, of the order Rhynchocephalia, which has a single genus, Hatteria (Fig. 396), existing to-day. The most interesting reptiles, however, belong to two orders now extinct, the Theromorpha (Gr. *θήρ*, beast, and *μορφή*, form) and the Sauropterygia (Gr. *σαῦρος*, lizard, and *πτέρυξ*, wing). The former were lizardlike, with appendages adapted to walking on land; they are confined to the rocks of the Permian and Triassic, and have been found in Africa, Europe, and North America. The latter were also lizardlike, some small but others very large; they attained their greatest development in the Mesozoic era, so we may defer a description of them for the present. An interesting genus of the Dipnoi appears here, Ceratodus (Fig. 397), which still exists in Australia; it is the only genus of Palæozoic vertebrates which has persisted through all the succeeding geological periods to the present time.

These five periods, from the Cambrian to the Permian inclusive, constitute the Palæozoic group or era, so called because the vast majority of the animals living then were very different from those at present inhabiting the earth; they have almost

FIG. 398. *Lingula*, one of the oldest Brachiopoda; natural size. (Drawn from specimen.)

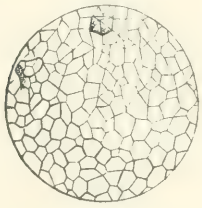


FIG. 399. *Echinosphærites aurantium*, one of the Cystoidea; fossil. (Drawn from specimen by the author.)

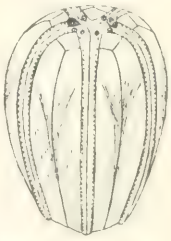


FIG. 400. *Granatocrinus*, one of the Blastoidea; fossil. (Drawn from specimen by the author.)

entirely become extinct, leaving no descendants. In some cases there may be only a single living representative of a group that at this early time was very abundant. Thus, the only living genus

of the tetrabranchiate Cephalopoda, type Mollusca, is the chambered or pearly nautilus. Fossil species related to this appear in the Silurian rocks, and the Nautiloids, as they are called, reached their greatest development in the Palæozoic era. But some genera that lived at this inconceivably remote time still inhabit the earth. As an example, among the invertebrates we may mention a genus of the Brachiopoda, Lingula (Fig. 398), which occurs in the Silurian rocks and is found in our oceans

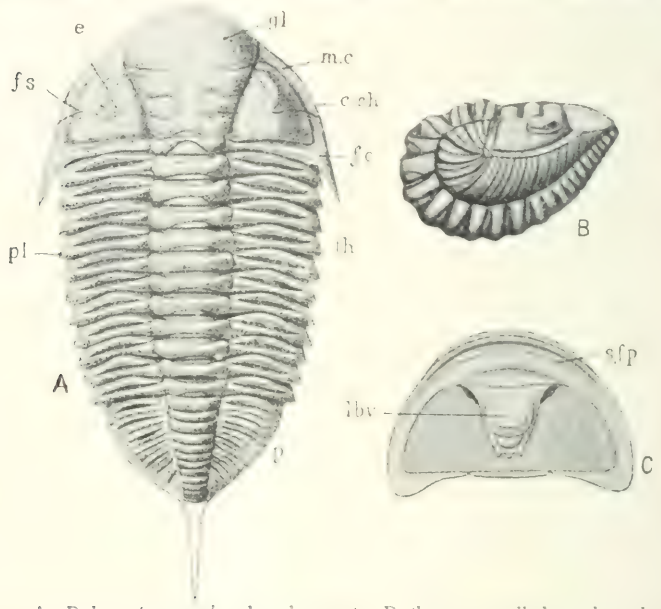



FIG. 401. A, *Dalmanites socialis*, dorsal aspect; B, the same rolled up, lateral aspect; C, ventral side of head of *Phacops fecundus*. *c.sh*, cephalic shield; *e*, eye; *f.c*, fixed cheek; *f.s*, frontal suture; *gl*, glabella; *lbr*, labrum; *m.c*, movable cheek; *p*, pygidium; *pl*, pleura; *s.f.p*, subfrontal plate; *th*, thorax. (After Gerstaecker, from Parker and Haswell's Textbook.)

to-day. Of the vertebrates there is only one genus that has survived, Ceratodus, the lungfish already mentioned. How long this era lasted we cannot say, but various attempts have been made to estimate the number of years necessary for building up the various formations, and one of these, based on the sedimentary rocks of North America, gives us 17,500,000 years for the duration of the Palæozoic era. If this period of time, which is beyond human conception, is even approximately correct, it is not surprising that so many different classes and

orders should have come into existence, and that some should even have attained their maximum development in number of species and differentiation of structure, and have died out so that they do not appear in succeeding eras. This is true of two classes of the Echinodermata, the Cystoidea and the Blastoidea (Figs. 399 and 400), while the Crinoidea were much more abundant then than at any later period; their remains form great beds of limestone in the Silurian and Carboniferous periods.

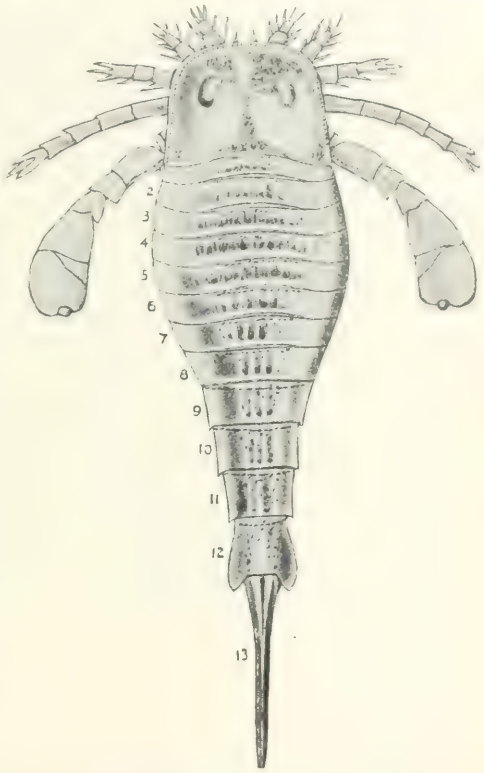



FIG. 402. *Eurypterus fischeri*, from the Silurian. (From Parker and Haswell's Text-book.)

Another group which became extinct in the Palæozoic is the Trilobitæ (Fig. 401), already referred to in Chapter VII in connection with the Crustacea, and the same is true of the various insects which lived at that time; they are known collectively as the Palæodictyoptera (Gr. *παλαιός*, ancient, *δίκτυον*, net, and *πτερόν*, wing). Of the vertebrates the Ostracodermi are not found above the Permian. But in all the Palæozoic rocks, requiring so long a period for their formation, there is no trace of the remains of the warm-blooded animals, the birds and mammals. These first appear in the next era, the Mesozoic, which comprises for the most part animals intermediate in structure between the Palæozoic and the Cenozoic. The estimated age of the Mesozoic era, based on the same data as the age of the Palæozoic, is 7,200,000 years, and, as we

have already noted in Chapter II, it is divided into three periods or formations, the Triassic or oldest, the Jurassic, and the Cretaceous or most recent.

While many genera and in some cases entire orders of invertebrates become extinct in the Palæozoic, many persist into the Mesozoic, and new groups appear. The Brachiopoda are much less numerous than in the preceding era. The Crustacea appeared in the Cambrian, lost the Trilobitæ and some of their allies (Fig. 402) before the end of the Palæozoic, were increased by the addition of the Xiphosura, or king crabs (Fig. 403), in the Triassic, and by the true decapod crabs in the Cretaceous. Orders of insects which exist to-day first made their appearance in the Triassic, where we find the Orthoptera, Neuroptera, and Coleoptera; the Hemiptera, Lepidoptera, Diptera, and Hymenoptera appear in the Jurassic. Many new genera of the Mollusca are found in the Mesozoic; the Nautiloids whose great development in the Palæozoic we have noted, have nearly disappeared in the Triassic even; in them the septa which divide the shell into chambers are smooth and curved, and the lines or sutures where they meet the wall of the shell are simple curved lines. Clearly related to the Nautiloids, is another group called the Ammonites, having a similar shell, but with folded septa, and sutures which are irregular, lobed, or even foliaceous. Some of the Ammonites appear in the Palæozoic, but the majority are confined to the Mesozoic, where they attain a high degree of development, becoming extinct before the next era. The shape of the shell varies much in the fossil tetrabranchiate

FIG. 403. *Limulus polyphemus*, the horseshoe crab, adult female; actual length, forty-six centimeters. (Photographed from a dried specimen by the author.)

Cephalopoda; some are straight and conical, some conical but slightly curved; others exhibit a slight attempt at coiling; while still others are more or less closely coiled, either in conical spirals or flat. Some attained a very great size; thus, in the genus Orthoceras, having a straight conical shell, a Nautiloid of the Palæozoic, the shell attains in some species a length of two meters and a diameter of a third of a meter. The oldest representatives of the dibranchiate Cephalopoda are found in the Belemnites, which had internal, conical shells with chambers; they extend from the Triassic to the Cretaceous inclusive and have no living representatives. Other dibranchiate Cephalopoda, however, appear in the Mesozoic, and are in their maximum degree of development at the present day.

The Mesozoic vertebrates are of great interest. Remains of the Teleostei are found first in the Cretaceous, and some of the same genera found there are living to-day, such as the herring and pike. The group of salamander-like Amphibia called the Stegocephali, represented by the suborder Labyrinthodonta (Gr. λαβύρινθος, labyrinth, and ὀδούς, tooth), so called because of the complicated structure of the teeth, which appeared in the Palæozoic, extends into the Triassic, where it becomes extinct. These animals varied in length from ten centimeters to several meters; the skull of one measured some sixty centimeters in breadth and ninety in length, and the skin was provided with hard, bony plates, such as are found in no living amphibia.

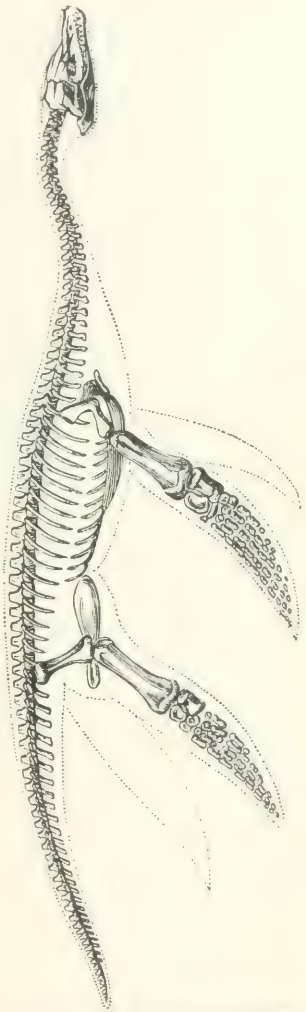


FIG. 404. *Plesiosaurus dolichodeirus*, restored. (After Owen, from Parker and Haswell's Text-book.)

The Reptilia of the Mesozoic were for the most part very different from those living to-day, but some representatives of existing orders appeared then. The Chelonia and Crocodilia date from the Triassic, the Lacertilia from the Jurassic, and the Ophidia from the Cretaceous; but several orders arose and became extinct in the Mesozoic era. The Sauropterygia, to which we have already referred as arising in the Permian, extended through the Mesozoic. Some were relatively small, but others, like the Plesiosaurus (Fig. 404), attained a length of twelve meters. The body was lizard-like, with a small head, long neck, two pairs of paddle-like appendages, and a relatively short tail. Plesiosaurus was marine, and lived probably in the shallower waters near the shore.

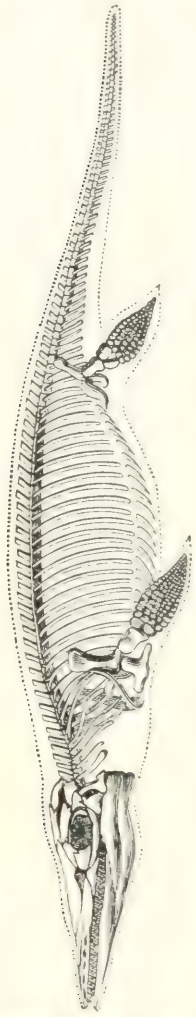


Fig. 405. [illegible]. (After Owen, from Parker and Haswell's Text-book.)

The Ichthyopterygia (Gr. *ἰχθύς*, fish, and *πτερύξ*, fin) were reptiles which inhabited salt water and in some cases attained a length of from nine to twelve meters. The genus Ichthyosaurus (Fig. 405) is a typical representative. The head was large, and there was no neck; there were two pairs of paddle-like appendages and a long tail. From various details of skeletal structure we know that Ichthyosaurus went out for considerable distances in the open waters, but was able to move about to some extent on the shore. It was probably able to descend to considerable depths and was a very carnivorous and voracious animal, feeding on fish, especially ganoids, which were abundant at that time. Remains of the Ichthyopterygia have been found very widely distributed geographically, in Europe, Africa, Asia, Australia, and North America, in both Arctic and tropical regions, from the Triassic to the Cretaceous inclusive.

A third group of Mesozoic reptiles, the Dinosauria (Gr. *δεινος*,

mighty, and *σαῦρος*, lizard), contained many genera, some of which were among the largest land animals that have ever existed. In some the skin appears to have been naked, in others there was a bony external skeleton sometimes provided with spines. The shape of the body varied much. One of the most familiar genera was Iguanodon (Fig. 406), which had relatively small fore feet but large hind legs and a well-developed tail, and it appears to have rested usually, much like a kangaroo,

FIG. 406. *Iguanodon bernissartensis*, one sixtieth natural size. *co*, coracoid; *is*, ischium; *p*, pubis (pectineal process); *pp*, post-pubic process (pubis); I–IV, I–V, digits. (After Dollo, from Parker and Haswell's Text-book.)

on its hind legs and tail; the total length of the body was from fifteen to eighteen meters. It appears to have been entirely herbivorous, feeding largely on the foliage of trees. Another genus, Atlantosaurus, belonging to this same group, contains some gigantic species. One found in Colorado was from fifteen to eighteen meters long, and when erect at least nine meters in height; it was an herbivorous land animal. The Dinosauria, like the Ichthyopterygia, are found in the Triassic, Jurassic, and Cretaceous.

The Pterosauria (Gr. *πτερόν*, wing, and *σαῦρος*, lizard) consti-

tute the order of flying reptiles. The skull resembled that of a bird in general shape (Fig. 407); teeth were present in some, while others appear to have had a horny beak; the neck was fairly long. The bones of the outermost digit on the anterior appendages were greatly elongated, thus affording attachment to a membrane extending along the arm, the side of the body, and along the posterior appendage, forming a wing, something like the wing of a bat (Fig. 408). The tail was in some cases short, in others very long. The resemblance to birds is very great in the structure, form, and arrangement of the bones, and in the shape of the brain, which was decidedly avian. These reptiles varied much in size; most of them were not very large, but some had an expanse of wing of over six meters. They are found only in Jurassic and Cretaceous formations.

FIG. 407. *Pterodactylus spectabilis*, a fossil flying reptile; three fourths of the natural size. (After von Mayer, from Parker and Haswell's Text-book.)

The fifth order of reptiles, the Pythonomorpha (Gr. Πύθων, Python, and μορφή, form), consisted of marine animals which very rarely came to land; they had the body greatly elongated, snakelike, at times attaining a length of about twenty-three meters. The appendages were paddlelike, and in some cases there were bony plates in the skin. They are found only in the Cretaceous formations.

The earliest known fossil bird is represented by a single genus and a single species, *Archæopteryx lithographica* (Fig. 409), of which two specimens have been found in the Jurassic rocks of Bavaria. It had teeth in both jaws. The tail was long, of many separate vertebræ, and with feathers in a row on each

side. No nearly related genera are known. Two other extinct orders are found in the Cretaceous, the Odontolcæ (Gr. *ὀδούς*,

FIG. 408. *Ramphorhynchus*, an extinct flying reptile; restored. (After Zittel, from Parker and Haswell's Text-book.)

tooth, and *ὀλκός*, furrow) (Fig. 410) and the Ichthyornithæ (Gr. *ἰχθύς*, fish, and *ὄρνις*, bird) (Fig. 411). A typical representative of the former order is Hesperornis, which formerly lived in North America; it was a large diving and swimming bird, with teeth in both upper and lower jaws, and stood nearly two

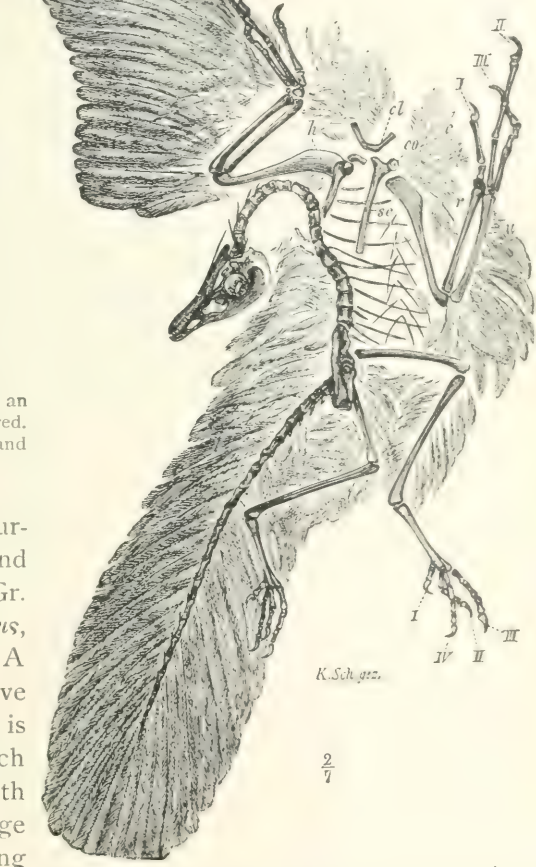



FIG. 409. *Archæopteryx lithographica*, from the specimen at Berlin; two sevenths the natural size; a fossil bird from the Upper Jurassic of Bavaria. *c*, carpel; *cl*, furcula; *co*, coracoid, *h*, humerus; *r*, radius; *sc*, scapula; *u*, ulna; I–IV, digits. (From Parker and Haswell's Text-book.)

meters high. Ichthyornis may be mentioned as an example of the latter order; it likewise lived in North America, was something like the terns, but had teeth in both jaws. Thus the

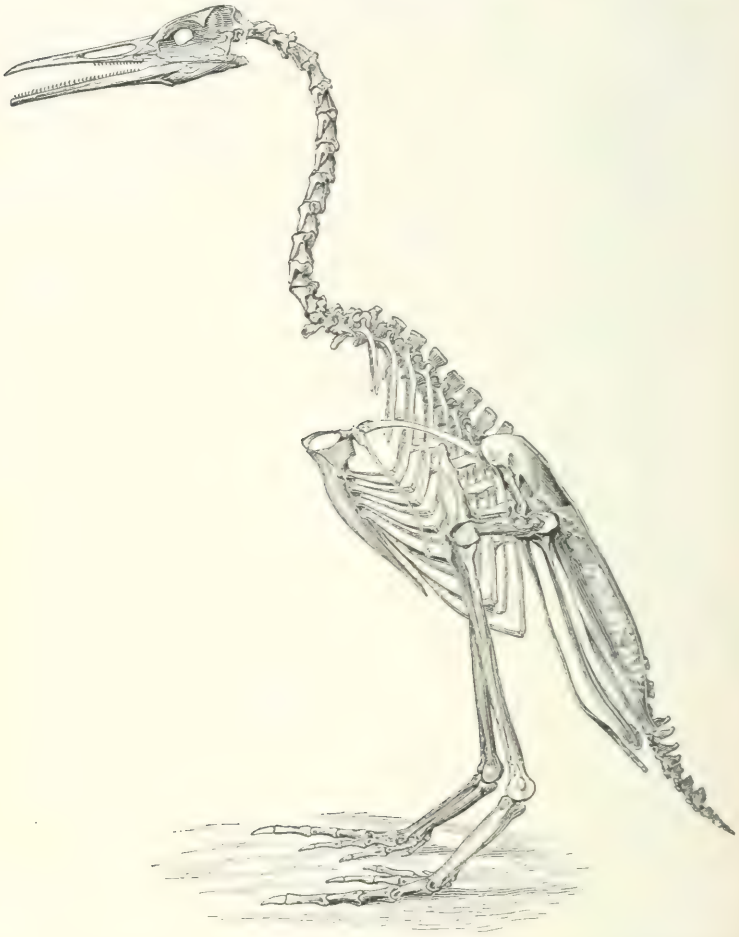


FIG. 410. *Hesperornis regalis*, a fossil diving and swimming bird of North America; skeleton, restored. (After Marsh, from Parker and Haswell's Text-book.)

Mesozoic birds are clearly separated from all existing orders, for, as we have already noted, no living bird is provided with teeth.

Fossil remains of the Mammalia are first found in the Triassic. But since these, as well as the mammalian remains in the Jurassic,

consist almost exclusively of jawbones and teeth, it is difficult to fix their precise relationship to existing orders. Some appear to have been related to the Monotremata and others to the Marsupialia; they were of small size. The only mammalian

FIG. 411. *Ichthyornis victor*, a fossil ternlike bird of North America; skeleton, restored. (After Marsh, from Parker and Haswell's Text-book.)

fossils in Cretaceous rock have been found in a few places in North America. We can, therefore, form no detailed conception of the Mesozoic Mammalia.

When we come to the Cenozoic era, we have a relatively much shorter period of time to deal with. This has been esti-

mated to cover about three million years, and we shall find the fossils which it contains rapidly approaching the structure of animals living to-day. In the Tertiary, with its three periods, Eocene, Miocene, and Pliocene, we find not only existing families of the invertebrates, but even many existing genera; yet even in the Pliocene the species are for the most part different from those of to-day, having become extinct and been replaced by modern species. The Bryozoa or Polyzoa, which date back to the Cambrian, were very abundant in certain regions during the Tertiary, where their remains form calcareous deposits of very great extent. The allied Brachiopoda, however, show a gradual but sure decrease in numbers; thus there are 106 genera in the Palæozoic formations, 34 in the Mesozoic, and only 21 in the Cenozoic. All the living orders of the Arachnida were present in the Tertiary, although some had already long existed; thus the scorpions date back to the Silurian, the spiders to the Carboniferous.

Of the Tertiary vertebrates we find that all the fishes belong to existing orders. The curious amphibian Stegocephali disappeared early in the Jurassic period of the Mesozoic, and the first remains of the Urodela and the Anura occur in the Eocene. All the reptiles belong to existing orders, but some were much larger than at present, as, for example, the gigantic land tortoise of the Miocene in India, which measured six meters in length and over two meters in height. Many existing orders of birds appear in the Eocene, and several which have since become extinct; by the middle of the Tertiary nearly all of the existing orders are represented. It is in this era that the Mammalia become most conspicuous and attain their highest degree of development. There are no remains of the Monotremata in the Tertiary rocks. The Tertiary Marsupialia are found in Europe, North America, and South America, although to-day there are no representatives of this group in Europe. All of the existing orders of the Placentalia are represented by Tertiary fossils, and all appeared as early as the Eocene, with the exception of the Edentata, which are found in the Miocene, although they may have lived in the Eocene as well. Some suborders also, such as the Proboscidea and the Anthropoidea, did not appear until the Miocene. In addition there are several large groups,

suborders, and families, which have become extinct in one or another of the Tertiary periods.

The most interesting representatives of the Edentata occur in the Pleistocene of North and South America, and at that time this order reached its greatest development; but even in the Miocene some gigantic species have been found in Europe, although there are no Edentata on that continent to-day. The Sirenia are represented by two families, one now extinct, the other that of the dugongs, of which specimens have been found in France and California. Cetacea are found throughout the Tertiary. The toothless, or whalebone, whales are found in the Miocene and the Pliocene. The genus Delphinus, which includes the common dolphins, dates back to the Miocene. Some interesting extinct genera (Fig. 412) have been found, such as Zeuglodon, which occurs throughout the Tertiary in Europe, Egypt, and North America; one of the largest specimens is from the Eocene of the United States, having a length of about twenty-one meters.

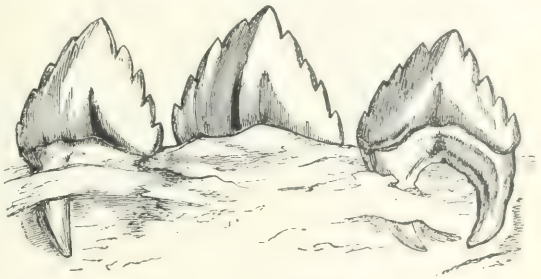


FIG. 412. *Squalodon*, an extinct genus of whales with heterodont dentition, which appeared in the Miocene; three of the molar teeth from the lower jaw. (After Flower, from Parker and Haswell's Text-book.)

The Ungulata are represented by an immense number of fossil species and genera; many families have become extinct. One of the most interesting features of the fossil Perissodactyla is the progressive reduction of the lateral digits as we pass from the earlier to the more recent genera. The family Equidæ, represented to-day by the horse, the ass, and the zebra, is a good example. The little Eohippus, about the size of a fox, of the Lower Eocene beds of New Mexico, had five digits on each of its anteror appendages, three on the posterior; the Orohippus, of slightly higher beds, had four digits on each fore leg and three on the hind legs. In the Lower Miocene beds we find the genus Mesohippus, with three digits on each foot; toward the

close of the Miocene period we find the first appearance of the modern genus Equus, with one digit on each foot. In this series the first digit to disappear was the first, or innermost, then the fifth, or outermost, and finally the second and fourth, leaving the third, which forms the foot of the present horse. In the Artiodactyla there is likewise a progressive reduction in the lateral digits and a progressive development of tusks and of horns. The antlers of the deer furnish an interesting example. It is a familiar fact that in the true deer antlers are borne by the male only, except in the case of the reindeer, where both sexes bear horns; and the antlers are yearly growths, falling off and being replaced by new each year. The second year after birth the male develops a pair of horns which are unbranched; these are replaced the next year by a pair with two prongs or points. The following year horns develop with three or more points, and this process goes on in many deer, so that an old male will have very complicated antlers with a large number of points. In the Miocene deer, however, we find genera with antlers which never had more than two points; in many of the Pliocene deer there were only three points; in the Post-tertiary the antlers become as complex as in many existing genera.

Of the Proboscidea we find the elephant in the Miocene of India and in the Pliocene of Europe, Asia, and North America; the extinct mastodon, which differed from the elephant chiefly in the form of its teeth, is found in the Miocene of Europe and Asia and in the Pliocene of North America. One of the most interesting of the Tertiary Proboscidea is the extinct genus Dinotherium (Fig. 413) of the Miocene, whose huge skull measured about a meter in length. The tusks were directed downward and came from the lower jaw. The extinct genus Dinoceras, found only in the Eocene of North America, exhibits resemblances to both the Perissodactyla and the Proboscidea; it was about as large as an elephant and is peculiarly interesting because of the size of the brain, which was smaller in proportion to the rest of the body than the brain of any other mammal. There are several other orders of extinct ungulates found in the Tertiary, for the most part much more primitive in structure than existing genera, but not of sufficient interest to be considered here.

The Rodentia have left remains throughout the Tertiary; many of their oldest fossils belong to existing genera, but several families have become extinct. Both the Insectivora and the Chiroptera are represented by fossils as early as the Eocene, and the genera then living were very similar to those existing to-day.

The Carnivora are found throughout the Tertiary, but the genera are all much less specialized than at present, and repre-

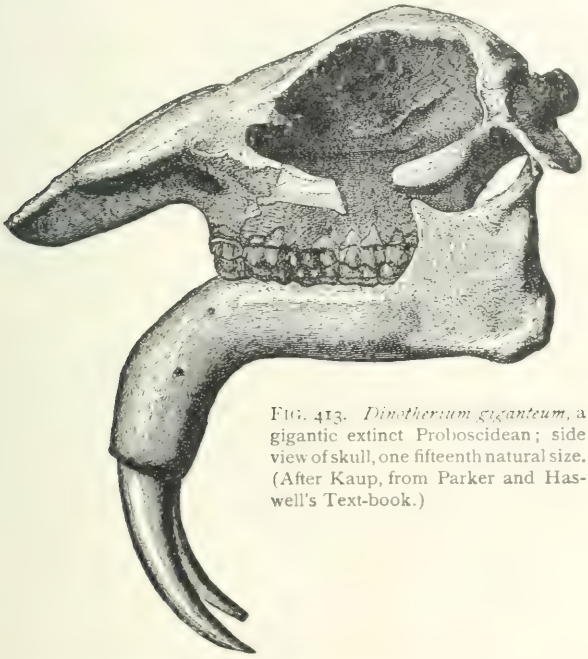


FIG. 413. *Dinotherium giganteum*, a gigantic extinct Proboscidean; side view of skull, one fifteenth natural size. (After Kaup, from Parker and Haswell's Text-book.)

sent conditions intermediate between the many sharply differentiated genera existing to-day. Thus we find connecting links, as it were, which join the dogs, bears, hyenas, and cats with one another. The Pinnipedia do not appear until the middle and more recent portions of the Tertiary; sea lions are found in the Miocene, seals and walruses in the Pliocene.

The Primates appear in the Eocene where they are represented by the Lemuroidea. Remains of the Old World monkeys are found in the Miocene and the Pliocene of Europe and Asia; there are species of both extinct and existing genera. Species

allied to the gibbons and gorilla occur in the Miocene, to the orang and chimpanzee in the Pliocene. In the Miocene of India flints have been found which appear to have been of human manufacture; in the Upper Pliocene of Java there were discovered in 1894 portions of the remains of an animal which has been called *Pithecanthropos erectus;* by some scientists it is regarded as belonging to a low race of man, by some as a large, manlike ape, while others considered it as intermediate between the higher apes and man. If the first of these three views is correct, then the earliest human remains as yet discovered date back to the Pliocene; if the others are correct we have no actual remains until the Pleistocene.

If we consider the entire class of Tertiary Mammalia, we are most impressed with the generalized type of structure which its representatives present, a phenomenon which holds in general for all animal classes when they first appear in fossil remains. As we pass from the earlier to the more recent mammals, each group tends to higher and higher specialization as it approaches existing species, a fact which will be more apparent when we come to consider Post-tertiary animal life.

The Quaternary or Post-tertiary period has been estimated to occupy about one twentieth of the period of time which has elapsed since the beginning of the Cambrian, and to be about half as long as the Tertiary. Very many species which exist to-day are represented in the Pleistocene fossils, and likewise many extinct species. The glacial period which occurred at this time affected profoundly the geographical distribution of animals, for many species which until then occupied the northern hemisphere, in what are now its temperate and Arctic regions, afterward are found only in tropical regions, the great cold having caused them to migrate southward. There are fossils of some interesting birds which lived in the Pleistocene and became extinct during that period or in the succeeding Recent. These birds were wingless or had rudimentary wings, and hence were incapable of flight, and some of them attained an enormous size. The genus Dinornis (Fig. 414) of New Zealand contains species which stood three meters high. Other species of this same genus, although not so tall, had very massive skeletons, the toe bones almost rivaling those of the

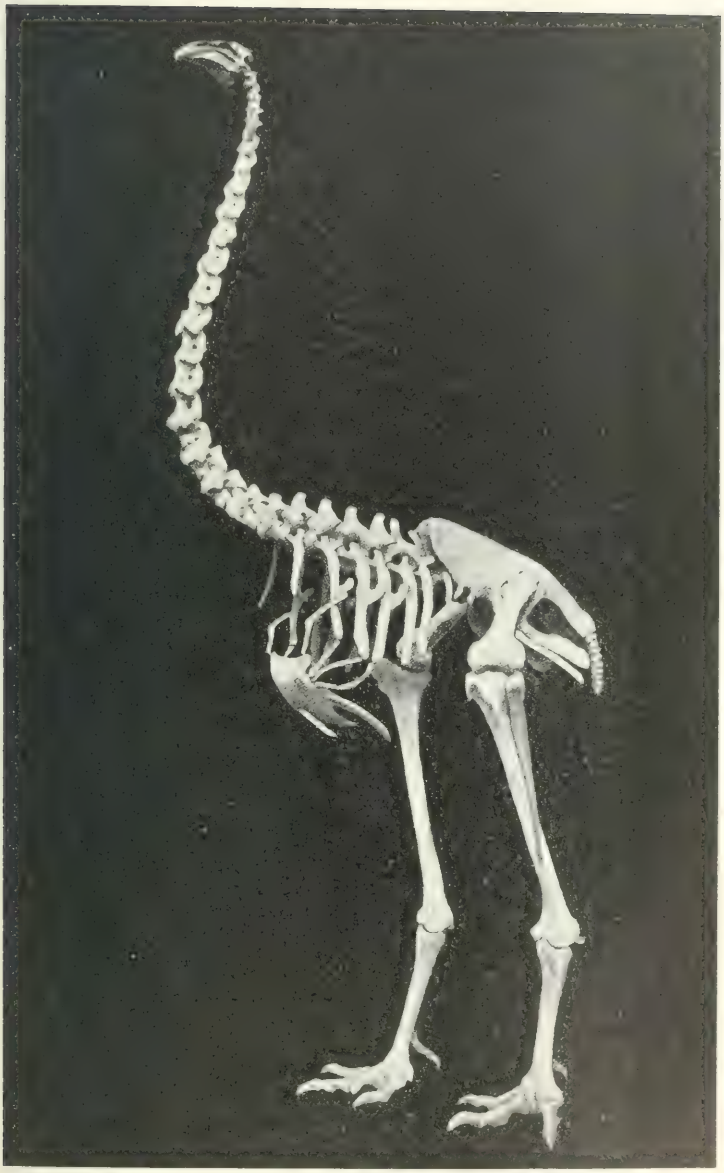


FIG. 414. *Dinornis robustus*, one of the moas; skeleton; actual height over two and three quarters meters (nine feet and a half). (After Parker and Haswell.)

elephant. These birds are called the moas and have certainly become extinct since man inhabited the earth. Their skeletons are very numerous in the most recent deposits. Other birds have been found in the Post-tertiary of Madagascar which rivaled the moas in size. With the bones of the genus Æpyornis have been found eggs measuring thirty-five centimeters in diameter. Some birds have become extinct within very recent times, such as the great auk (Fig. 415) and the dodo (Fig. 416), to which we have already referred.

FIG. 415. *Alca impennis*, the great auk, now extinct, and the smaller *Alca* (*Utamania*) *torda*, the razor-billed auk. (From a photograph provided by the American Museum of Natural History.)

The first remains of the Monotremata are found in the Pleistocene of Australia, and the species living then differ little except in size from the Australian Echidna of to-day. Of the Marsupialia the opossums have been found in the Tertiary of both Europe and America, and in the Pleistocene of America only. In the Tertiary of South America are remains of a genus of large marsupials, Diprotodon. All fossil marsupials except the Tertiary belong to the Pleistocene and appear to be confined to Australia; the genus Diprotodon is represented here also, and attained the size of a rhinoceros.

Many other extinct marsupials have been found in the Australian bone-caves, often of gigantic size, and also the bones of almost all the living representatives.

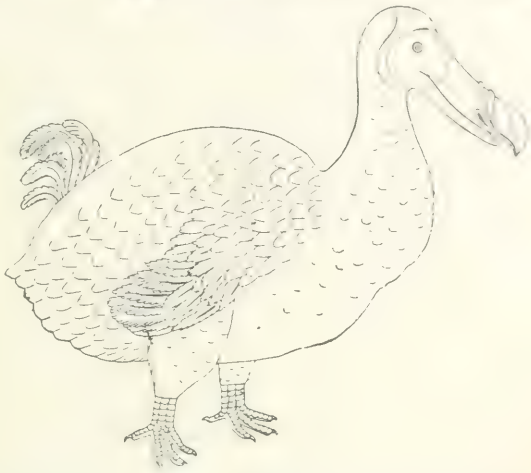


FIG. 416. *Didus ineptus*, the extinct dodo; color gray, with yellow wing and tail feathers; natural size, 80 cm. high; weight, 12.5 kg. (From Ludwig-Leunis' Synopsis der Thierkunde.)

The Edentata appear to have attained their greatest development in the Post-tertiary period; their remains are confined to North and South America. Among the most remarkable are the now extinct ground sloths, which attained a gigantic size, lived exclusively on the ground instead of in trees as do the sloths to-day, and fed on plants and the leaves of trees. The genus Megatherium attained a length of from three and a half to five and a half meters, and its bones were more massive than those of the elephant. The genus Mylodon (Fig. 417) was smaller, about three meters and a half in length, but its habits were much like those of the Megatherium; these animals lived in both North and South America, and did not exist later than

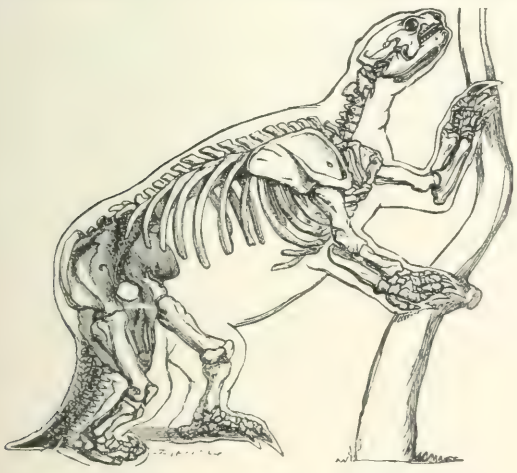


FIG. 417. *Mylodon robustus*, a gigantic fossil Edentate resembling the ant-eaters and the sloth; restored. (After Owen, from Parker and Haswell's Text-book.)

the Pleistocene. Curious animals, resembling the little armadillos of to-day, likewise lived in the American Pleistocene; the extinct genus Glyptodon is a good example (Fig. 418). It attained a length of nearly three meters and was covered on the dorsal surface by a greatly arched shell consisting of fused bony plates in the integument; this external skeleton was not jointed, however, as in the present armadillos, and so the animal could not roll itself up.

The Ungulata have some very interesting representatives in the Post-tertiary period. Here we find the woolly rhinoceros: it had two horns, one anterior to the other; its skin was without folds and provided with a woolly covering. It lived in the

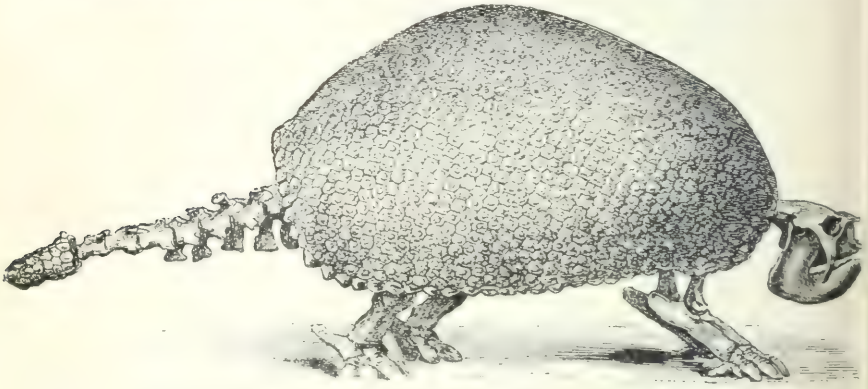


FIG. 418. *Glyptodon clavipes*, a fossil Edentate resembling the armadillos. (After Owen, from Parker and Haswell's Text-book.)

north, having the same geographical distribution as the mammoth, although its first appearance on the earth was much later than the first appearance of the mammoth. The reindeer had a much wider distribution in the Pleistocene period than at present, extending in Europe as far south as the Pyrenees. The extinct Irish elk, *Cervus megaceros* or *Megaceros hibernicus*, is noteworthy because of its huge antlers, which attain an expanse of three meters from tip to tip. The wild bull of the Pleistocene, *Bos primigenius*, is believed to be the same as the present domestic ox, *Bos taurus*, although much larger than the latter. The Mammoth, *Elephas primigenius*, appears in the early Pleistocene and lived until very recent times, for a carved representation of it has been found. It lived in the

north, and from specimens found embedded in the ice of Siberia we know that it had a woolly covering, about twenty-five centimeters long, of a reddish brown color, interspersed with somewhat longer, coarser black hairs. The mammoth stood nearly three meters high and was about five meters long, exclusive of the huge tusks, which were curved almost into a circle. In contrast to this species are the little elephants of Malta, which lived in the Pleistocene; one species, *Elephas melitensis*, was about a meter and a third high, another, *Elephas falconeri*, only about seventy-five to ninety centimeters. The mastodon, *Mastodon giganteus*, differed from the elephant chiefly in the form of its teeth. It appeared in Europe and Asia in the Miocene and became extinct in the Pliocene; it appeared in North America in the Pliocene and lived through the Pleistocene, ranging from Canada to Texas; it was slightly larger than the mammoth, and its tusks measured over three and a half meters in length.

In the Rodentia we find a large, beaver-like animal in the North American Pleistocene, called *Castoroides ohioensis*; it was much larger than any existing rodent, being a meter and a half in length.

There are several Post-tertiary Carnivora which resemble existing species very minutely and may be identical with them; the chief difference lies in the greater size of the older individuals. The two most important bears were *Ursus priscus*, which was probably the same as the present grizzly bear, *Ursus ferox* (or *horribilis*), and the cave bear, *Ursus spelæus*, whose remains occur chiefly in cavern deposits; it was larger than any of our present bears. The European cave lion, *Felis spelæa*, was probably the same as our *Felis leo*. Both the cave bear and the cave lion were contemporaneous with the woolly rhinoceros, the Irish elk, the wild bull, and the mammoth.

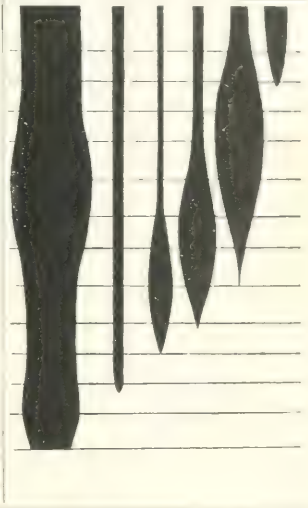
Among the Primates, remains of New World monkeys have been found in South America only, in the Pleistocene formations. The Old World monkeys, as we have already noted, appeared much earlier, in the Tertiary. Human remains, in the form of bones or manufactured implements, are found in various Pleistocene deposits and are often associated with the bones of other Mammalia living at that time.

This very brief survey of the field of palæontology brings to light a few fundamental biological facts which we shall see later have a great theoretical interest. There is no evidence in facts that all classes of animals came into existence in the same geological period; on the contrary, the classes which we recognize to-day as the most highly organized in the animal series seem to have been the last to make their appearance on the earth. We note, further, that when any group of animals first appears it presents, as a rule, a much more generalized type of structure than its later representatives; fossil remains of many adult animals possess in many respects the structure of the embryos of existing groups. Thus the older fossil fishes and reptiles had the vertebral column cartilaginous or incompletely ossified. The older remains of reptiles and mammals show that the structure and shape of the skull were like those of the embryo of recent genera. We have seen that many groups have become extinct, just why it is not always easy to say. During the last few hundred years several animals have become extinct through man, and many more are likely to become so in the near future. In the past it has probably been much the same. The stronger, the more voracious, the more cunning animals have preyed on their weaker or more stupid neighbors, and the result may have been extinction. Others may have been unable to meet the changed conditions of climate or temperature to which they were subjected, an inability resulting, perhaps, from too high a degree of specialization along some one line; and thus extinction has resulted. But whatever the cause, it has probably been, in the majority of cases at least, a gradual one; the old belief that violent interruptions of the action of natural forces led to the wiping out of entire genera or families has been abandoned. We have already noted some of the reasons why the palæontological record is so incomplete; with these factors in mind we marvel not at its incompleteness, but rather at its completeness.

The attempt has often been made to represent diagrammatically the relations of the various geological periods to one another, and the origin and development of the different groups of animals. Such diagrams are necessarily more or less inaccurate and misleading, but they serve as an aid to the elementary

student by giving a certain graphic reality to what may otherwise appear as mere words; for this reason the following table is appended, in which the relative length of the various periods is indicated by numbers merely.

| Era | Period | Percentage Duration according to Williams[1] | Duration in Years according to Walcott | Invertebrata | Fishes | Amphibians | Reptiles | Mammals | Man |
|---|---|---|---|---|---|---|---|---|---|
| Cenozoic | Recent | 5 | 3,000,000 | | | | | | |
| | Pleistocene | | | | | | | | |
| | Pliocene | | | | | | | | |
| | Miocene | 10 | | | | | | | |
| | Eocene | | | | | | | | |
| Mesozoic | Cretaceous | 10 | 7,200,000 | | | | | | |
| | Jurassic | 5 | | | | | | | |
| | Triassic | 5 | | | | | | | |
| Palæozoic | Permian | 15 | 17,500,000 | | | | | | |
| | Carboniferous | | | | | | | | |
| | Devonian | 15 | | | | | | | |
| | Silurian | 20 | | | | | | | |
| | Cambrian | 15 | | | | | | | |
| Archæan | Laurentian | | | | | | | | |



[1] The total period from the beginning of the Cambrian to the present time is taken as 100.

# CHAPTER XI

## THE DISTRIBUTION OF ANIMALS

In the preceding chapter we have considered the distribution of animals in time; we may next glance at their distribution on the earth to-day, taking first their vertical or bathymetrical distribution, and then their horizontal or geographical distribution. The animals which collectively inhabit any region constitute its fauna, just as the plants in any particular place form the flora of that place. Concerning the vertical distribution of animals, or as we may with equal propriety call it, their habitat, we have to do with marine animals, fresh-water animals, terrestrial animals, and aërial animals.

A few facts concerning the physical geography of the ocean are necessary to even a brief consideration of its animal life. The ocean is far from being of uniform depth. The deepest points known are much restricted in area and measure about 9000 meters; the greater portion of the ocean bottom is from 5000 to 6000 meters below the surface. The portion of the continents above sea level does not pass abruptly to this great depth as a rule, nor is there a gradual slope from the shore line to the deep sea. Instead, the land passes under the water in a gentle slope to a depth of about 200 meters; then it plunges very precipitously as a rule to a depth of 2000 meters. The portion of the land covered thus by relatively shallow water is called the continental shelf, and varies much in width at various points on the different continents. Thus the shelf on the eastern coast of North America is relatively broad, on the western coast very narrow.

Not only is there great variation in the general topography of the ocean bed, but the nature of the deposits which cover it is very different in different regions. The portion of the ocean bottom which adjoins the shore is covered for a variable distance

with substances derived from the wearing away of the land by the action of the waves and tides, with the sand, mud, and other substances brought down to the sea by rivers, and with the skeletal remains of many animals. All of these substances are spoken of as terrigenous deposits. Beyond this the ocean bed is covered for a considerable distance with deposits which consist largely of calcium carbonate, often as much as 90 per cent, and this is due to the presence of the shells of many minute animals, which live at the surface of the sea and as they die their skeletons fall to the bottom. In the shallower regions these deposits are called pteropod ooze, since they consist largely of the shells of the Pteropoda; in deeper waters the shells of certain Protozoa predominate, and there we have the characteristic grayish globigerina ooze, which extends to depths of 4000 or 5000 meters. Passing into still deeper waters, we find no trace of shells of calcium carbonate; they have all been dissolved. Instead we may find siliceous deposits, due chiefly to the siliceous shells of the minute plants called diatoms, and hence these deposits are spoken of as diatom ooze; this ooze, so far as we know at present, is confined to the southern ocean, a little north of the Antarctic Circle. Further, in the deepest portions of the western and central Pacific is found a radiolarian ooze, consisting of the shells of the Radiolaria, and hence siliceous. But the greater portion of the deep-sea basin beyond the region of the globigerina ooze is covered with the so-called red clay deposit, which varies in composition, but is composed chiefly of fragments of volcanic material. Sharks' teeth and some very hard bones of vertebrates have been found in this red clay, often inclosed in nodules of manganese or iron.

The temperature of the ocean is an important factor in the distribution of animal life; there we find no such range of temperature as there is on land. The highest temperature at the surface of the ocean is about 32° C. (89° F.), the lowest about −1° C. (30° F.), thus giving a range of less than 34° C. (60° F.), while on land man has been subjected to a temperature of 49° C. (120° F.) in the desert and of −61° C. (−78° F.) in Arctic regions, a range of about 110° C. (200° F.). It has been determined that the heat of the sun does not penetrate to a depth of more than 300 meters; then the temperature falls

rapidly until a depth of 600 or 800 meters is reached, when the water is about 3.3° C. (38° F.). Below 1000 meters the temperature is nearly uniform to the bottom of the ocean, and varies from below 4.5° C. (40° F.) to about 0.7° C. (33.3° F.), very near the freezing point. Hence marine animals are less able to withstand differences of heat and cold than are terrestrial animals.

A second important factor in marine life is the greater range of pressure to which the inhabitants of the ocean are subjected. The pressure increases very rapidly as we descend, but the deep-sea animals are differently constructed from those living near the surface; their tissues are looser and permeated with watery fluids so that the pressure within the body is proportional to the external pressure, else the animal would collapse. Many fishes on being brought to the surface from great depths literally blow up by the expansion of the gases in the swimming bladder as they come to regions of so greatly diminished pressure. At a depth of 2000 meters the pressure of the water may be said to be roughly 145 kilos to the square centimeter (about one ton to the square inch). But marine animals can adapt themselves to much greater variations in pressure than land animals, for many range through considerable depths of water, and so are subjected to very diverse pressures. Fishes and mollusks appear to be the only animals which suffer in any marked degree from a diminution in pressure.

Light is another important matter which affects the distribution of life in the ocean. Careful investigations seem to show that the light of the sun does not penetrate to a greater depth than about 400 meters. To quote from Dr. Alexander Agassiz, "We may imagine a reddish yellow twilight at a depth of about fifty fathoms, passing into a darker region near the hundred-fathom line; and finally, at two hundred fathoms, a district where the light is possibly that of a brilliant starlight night." Beyond this depth we have but little evidence of plant life; but even the depths of the oceans are not in absolute darkness, for, though the sunlight may not penetrate so far, many of the animals which inhabit those depths are phosphorescent, and emit a pale light by means of which they can see their prey and become visible to other animals.

In considering the distribution of animals in the ocean we may take up first the pelagic fauna, which consists of all animals which swim or float in the surface waters. The animals which can swim freely, such as fishes, dolphins, and whales, are sometimes spoken of collectively as the nekton of the fauna, while such as are more or less at the mercy of the waves and currents, as the jellyfishes, for example, constitute the plankton. Most of the animals of the plankton are found at the surface only when the waters are quiet; when the surface is ruffled they sink to less disturbed regions; some rise during the night only, others only in the morning or evening. The depth to which the pelagic fauna sinks to escape surface disturbances is a matter of some conjecture, but it is probably not over 300 meters. The animals constituting the marine plankton are for the most part highly transparent organisms, often very delicately tinted with various colors; at night they are phosphorescent to a marked degree. Here are found representatives of practically all the marine Protozoa; medusæ, siphonophores, and ctenophores are abundant. Many larvæ of the Echinodermata, Vermes, Crustacea, Mollusca, and Enteropneusta, are more or less widely distributed. A few of the Annelida are pelagic, and many of the smaller Crustacea, while the Mollusca are represented chiefly by the Pteropoda and Heteropoda. The unattached Tunicata are abundant, especially in tropical waters. Of the vertebrates many fishes are pelagic, and also the Cetacea,—whales, dolphins, porpoises, etc. The pelagic fauna as a whole occupies apparently a relatively shallow zone or stratum of water, probably not over four hundred meters in depth: as we approach the dry land it becomes continuous with the shore fauna, or littoral fauna, as it is technically called.

The littoral region is the richest in plant and animal life of any portion of the ocean. Here live many Protozoa, many sponges, nearly all the marine Cnidaria, and nearly all the Echinodermata; Turbellaria are found, the majority of the Nemertina, the Molluscoidea, the Polychæta, and the Gephyrea. Nearly all the marine Crustacea are represented here, as well as some insects and many of the marine Mollusca. *Balanoglossus*, the Tunicata, *Amphioxus*, and many fishes likewise belong to the littoral fauna, which includes also some of the

higher vertebrates, such as Chelonia and Sirenia, while some birds and the Pinnipedia may be added. The littoral fauna may be said to extend outward along the continental shelf to a depth of about three hundred meters. Beyond this point the continental shelf descends more or less precipitously into the deep sea, and along this slope we find animals more or less intermediate between these of the littoral fauna and the representatives of the deep-sea fauna; they have been called the continental fauna, extending downward to a depth of 1500 or 1600 meters. Below this depth, at which we have reached a temperature at least as low as 4.5° C. (40° F.) we come to the deep-sea or abyssal fauna. These limitations of depth for the various faunæ must, however, be taken only in the most general way; the animals of one fauna are not sharply marked off from those of another.

Our knowledge of deep-sea life is of very recent date, and there are still broad and alluring fields for investigation in this direction. As late as the middle of the nineteenth century it was believed by scientists that there was no life in the ocean below a depth of about 600 meters, despite the fact that fishermen had taken sharks from much greater depths, and had occasionally brought up siliceous sponges on their lines. In 1861 a telegraph cable in the Mediterranean was raised from a depth of 4000 meters, and living animals were found attached to it. At about this time Scandinavian investigators dredged several types of invertebrates from depths of from 2000 to nearly 3000 meters. Thus it became clear that even the depths of the ocean were inhabited by animals, and the question arose whether this deep-sea fauna was continuous vertically with the pelagic fauna. This was answered conclusively in the negative for the first time in 1880 by American scientists, who used nets which could be sent down closed to any depth, then opened and dragged for any desired distance, closed again and then brought to the surface; these nets, when dragged at a depth below what we have already noted for the extent of the pelagic fauna, invariably came up empty. Thus we see that along the edge of the continental shelf the littoral fauna divides, as it were, one portion extending outward over the surface of the ocean as the pelagic fauna, the other descending into the depths along the ocean bottom to form the abyssal fauna.

This abyssal fauna differs in many interesting features from any other fauna. It is essentially carnivorous: the larger and stronger fishes feed on the smaller and weaker; the latter feed on the invertebrates; the invertebrates feed on one another. In addition much food comes to the deep-sea animals from the death of the animals which make up the pelagic fauna. The latter, on dying, sink rapidly; jellylike animals are said to sink 4000 meters in less than three days: on the other hand, decay and disintegration are slow in deep water; but eventually such pelagic remains as are not devoured, disintegrate and, mingled with the water, form a sort of organic slime or broth, which is spread out in a thin layer over the oceanic basins, and doubtless serves as food for the smaller and less active abyssal animals. When first discovered it was believed to be a very primitive organism; it was preserved in alcohol, carefully studied under the microscope, given the generic name *Bathybius*, and very much theorized about. Later it was shown that what was called *Bathybius* was merely a flocculent precipitate of calcium sulphate which the organic matter had thrown down from the sea water in the presence of alcohol.

We have already noted the looseness of structure of deep-sea animals; many fishes have skeletons largely cartilaginous instead of bony, as in corresponding pelagic genera. Not a few abyssal species are blind, but as a rule the eyes are as well developed as in surface and littoral species, and are of use, as we have already noted, in the pale phosphorescent light with which many abyssal animals are endowed. Very many exhibit a brilliant coloration, possessing almost all the colors found in the littoral fauna; we can assign no use to such colors in the absence of sunlight at such great depths, but they afford a strong argument for the theory that the abyssal fauna is derived from the littoral fauna by a migration of the latter into deep water. This migration was doubtless comparatively recent, geologically speaking, for no palæozoic animals have been found in the deep sea; on the other hand, there are more representatives of Mesozoic and Tertiary types than we find to-day in the littoral fauna, and it is this which gives the abyssal fauna its peculiar facies. We may now glance at some of the more characteristic deep-sea types.

The Protozoa are here represented by a number of the Rhizopoda, some of which attain a considerable size, such as *Hyperammina elongata*, which grows to a length of fifteen millimeters. The most conspicuous and characteristic deep-sea sponges are the siliceous sponges, such as the Venus' flower basket, *Euplectella*, and the genus *Hyalonema*, then a few medusæ, sea anemones, and corals. All classes of the Echinodermata are richly represented, the stalked Crinoidea being notably abundant. Of the worms there are a few Bryozoa and Brachiopoda, and a number of tube-forming Chætopoda. Curious Crustacea are found there, a few barnacles, some gigantic Isopoda, thirty centimeters long, Schizopoda and Decapoda of odd shapes; there are several species of long-legged spider crabs, often of considerable size, as the *Lithodes agassizii*, whose carapace is about fifteen centimeters in diameter, while with legs extended it measures a meter from tip to tip. The Pycnogonida have some large representatives, one species having an expanse of sixty centimeters when the legs are extended. The Mollusca are not numerous; there are several species of Cephalopoda, and the giant squids occasionally cast up on the shore are doubtless deep-sea animals living along the slopes of the continental shelf. Finally, there are numerous fishes. It must be noted that many littoral and pelagic fishes can descend to considerable depths, some undertaking seasonal migrations; hence many families of surface fishes have been taken at depths between 200 and 1000 meters; only two or three extend to 1400 meters, and two or three to 2000 and 4000 meters. There are over thirty families of deep-sea fishes known which never occur in water less than 2000 meters deep. These are Teleostei, and many of them are grotesquely specialized, having enormous mouths, or excessively long teeth, or tactile organs developed out of all proportion to the rest of the body; many are phosphorescent either over the entire body, or in spots, especially on the head. The "ribbon fishes," *Regalecus*, occasionally cast ashore, are probably deep-sea types, although they have never been dredged from the depths; we have already called attention to them in Chapter IX as probably responsible for some sea-serpent fables. Few Selachii have as yet been discovered in the deep sea.

The fresh-water fauna does not present such a variety of types as the marine. It may be divided into lacustrine or lake fauna, and fluviatile or river fauna. The lacustrine fauna has not as yet been studied very extensively; in it we recognize, as in the ocean, a plankton of floating animals, mostly transparent, a nekton of swimming individuals, and a benthos of bottom types; the most abundant animals are certain Protozoa, the Rotifera, and small Crustacea. The fluviatile fauna contains large numbers of Protozoa, one family of sponges, a very few Cnidaria, the Hydridæ, and no Echinodermata; the worms are represented by Turbellaria, a few Nemertina, many Nematoda, some Bryozoa, many Rotifera, and Oligochæta and Hirudinea. Of the Crustacea all the Entomostraca are represented except the barnacles; of the Malacostraca are found Isopoda and Amphipoda and a few Decapoda, crabs and crayfishes. Some insects live in fresh water and some Mollusca, such as some of the Gastropoda and the Lamellibranchia. Fishes are numerous, representing the Cyclostomata, Ganoidei, Teleostei, and Dipnoi. All aquatic Amphibia inhabit fresh water. A few reptiles, such as the Crocodilia and some Chelonia, some birds, and a few mammals, such as the hippopotamus and some dolphins, belong essentially to the fresh-water fauna. In addition we find many larvæ in streams and ponds, such as the larvæ of the Trematoda, of many insects and of the terrestrial Amphibia. Animals living in subterranean streams and lakes are often blind and pale in color.

In the terrestrial fauna we have animals which live in the ground or on its surface or in trees. The lowest type of strictly terrestrial animals, not taking parasites into account, is the worms, of which we find representatives of the Turbellaria, Nemertina, Nematoda and Oligochæta. Of the Crustacea the wood lice (Isopoda) and some crabs (Decapoda) are more or less adapted to life on land. All of the Arachnida, Protracheata, and Myriapoda are terrestrial, and also many of the insects. Of the Mollusca we find only the majority of the Pulmonata. Some fishes can live for a time on land, notably a few Teleostei and the Dipnoi. The Gymnophiona and Anura are essentially terrestrial, and of the reptiles, the Lacertilia, most of the Ophidia, the Rhynchocephalia, and some Chelonia. Of the birds all

of the Dromæognathæ are terrestrial, and some of the Euornithes as well. The Impennes, or penguins, are really aquatic, belonging to the littoral marine fauna. Nearly all of the Mammalia are terrestrial. As we ascend to higher and higher points in a mountainous country, the facies of the fauna changes notably. The greater the elevation the fewer the animals we meet with, and in the higher regions they are so characteristically different from animals at lower levels that they may be said to constitute an alpine fauna. The chamois and mountain goats are familiar examples of alpine mammals, while many insects and birds are confined to these great altitudes.

In the aërial fauna are included such animals as are capable of sustaining themselves for long periods in the air, although fundamentally terrestrial; these are notably many insects, many birds, and the bats.

The study of the geographical distribution of animals discloses a number of interesting facts for the explanation of which we must turn to a considerable extent to geology and palæontology. It is a matter of common knowledge that certain animals are restricted to certain localities. Thus the hippopotamus is confined to Africa, the opossum to South America and a portion of North America, the reindeer to the Arctic regions But in considering the natural distribution of animals, we must be careful to eliminate such as have become inhabitants in any country through the agency of man. Thus the gypsy moth, the English sparrow, the horse, and the camel are living to-day in the United States, where none of them would now be found if it had not been brought from the Old World by man.

Scientists have divided the land into a number of zoogeographical regions as they are called, the basis for this division being the avian and mammalian faunæ, but the areas are so sharply marked off from one another that they hold good for the great majority of other land animals as well. Six zoögeographical regions are commonly recognized.

The Palæarctic region is the largest and comprises all Europe, Asia north of the Himalayas, including Japan, as well as Arabia and Africa north of the tropic of Cancer, and in addition Iceland and the islands in the eastern portion of the North Atlantic. It is a matter of some surprise that the fauna of Africa north of

# MAP OF THE WORLD DIVIDED INTO ZOO-GEOGRAPHICAL REGIONS.

London: Macmillan & Co.

the Sahara should resemble that of Europe rather than that of southern Africa; the desert, however, forms a most effective barrier to the migration of animals and so serves as a natural boundary for the two faunæ, while the Mediterranean has not always been the barrier that it appears to-day, for Europe and Africa were probably connected during the Pleistocene. The characteristics of the Palæarctic fauna are difficult to define in a general way, for they are characteristics of genera and species rather than of larger groups.

The Nearctic region consists of North America as far south as the northern portion of Mexico, and Greenland. The fauna is so much like the Palæarctic fauna that the two regions are sometimes considered as one, under the term Holarctic. Many birds are common to the two regions, several Ungulata, as oxen, elk, and deer, a number of rodents, such as hares, beavers, and squirrels, and Carnivora, foxes, wild cats, and bears. But the Nearctic possesses a number of animals which are entirely absent from the Palæarctic fauna, such as some fresh-water fishes, a number of tailed Amphibia, rattlesnakes, and some genera of Lacertilia, and many birds and mammals; of the last the opossum and raccoon are conspicuous examples.

The Ethiopian region consists of all Africa south of the tropic of Cancer, and the southern portion of Arabia, as well as Madagascar and a number of small islands off the coast of Africa. In Africa we find a number of fresh-water fishes not found elsewhere, notably one of the Dipnoi, *Protopterus*, and a number of reptiles and birds; the African ostrich is found in Arabia also. Distinctively Ethiopian are the aard-vark (Edentata), the zebra, very many antelopes, some species of the rhinoceros, the hippopotamus, and the African elephant, and also numerous Primates, such as lemurs, baboons, the gorilla, and the chimpanzee. Native deer, oxen, and bears are unknown. The fauna of Madagascar differs considerably from that of Africa in lacking nearly all of the above mammals except the lemurs, which are very abundant.

The Oriental region comprises India, Burmah, Siam, the southeastern portion of China, and a number of the East Indies, notably Sumatra, Java, Borneo, and the Philippines. The southeastern boundary of this region is an imaginary line, called Wal-

lace's line, passing between the small islands of Bali and Lombok, then between Borneo and Celebes, and on to the south and east of the Philippines. In this region are numerous serpents and a number of characteristic birds, such as the peacock and the argus pheasant; the tapir, rhinoceros, and Indian elephant are characteristic Ungulata. Deer are present, though absent from the Ethiopian fauna, and the same is true of bears. The tiger, many lemurs, the gibbons, and the orang-utang are all characteristic of the Oriental fauna.

The Australian region is made up of Australia and all the islands of the southern Pacific which lie to the southeast of Wallace's line; the largest of these are New Guinea and New Zealand. *Ceratodus*, one of the lungfishes, occurs in rivers in Australia, and Amphibia, lizards, and snakes are numerous. But in New Zealand there are very few Amphibia and lizards, and no snakes, turtles, or Crocodilia. Many characteristic birds are found in this region, of which we may mention merely the emus and cassowaries, the lyre bird, the bird of Paradise, and the cockatoos. The Mammalia are the most striking feature of the Australian fauna, for the Placentalia are almost entirely absent, the wild dog being one of the few exceptions; on the other hand the Monotremata, *Ornithorhynchus* and *Echidna*, are present here only, and almost all the marsupials are confined to this region. The fauna of the smaller islands of the Pacific are chiefly interesting because of the almost total absence of Mammalia.

Lastly, we have the Neotropical region, which includes North America, south of the Nearctic region, all of South America, the West Indies, the Galapagos Islands, and the other small islands in the vicinity of South America. Here we find the third representative of the Dipnoi, *Lepidosiren*; the electric eel, *Gymnotus*, is another characteristic fish. The Amphibia and all the large orders of Reptilia have genera here which are not found in any other region. Birds are very abundant; among the most striking are the humming birds, which are found in the Nearctic region also, and the rheas, or South American ostriches. The opossum is characteristic of the Neotropical region, although found in the Nearctic as well. Many Edentata are represented, such as the sloths, armadillos, and ant-eaters.

The tapir and llama are found here, and the rodents are more numerous than in any other country; the chinchillas, cavies, and their allies, the guinea pigs, may be mentioned as noteworthy examples. The marmosets and the monkeys with prehensile tails belong to South America and are absent in the West Indies. There are no sheep, oxen, or antelopes, and no Insectivora in South America, while the true swine are absent from both North and South America, although the peccaries are present in both.

Considering the distribution of the animal kingdom as a whole, we note that some animals are essentially cosmopolitan, they are represented in all the great geographical divisions of the earth; others, which we have just been considering, are restricted in distribution to one or two of the great zoogeographical regions. Many groups of animals had in the prehistoric past a very different distribution from what they have to-day; thus in the Pleistocene the elephant ranged over the greater part of the Holarctic region, while to-day it is found only in the Ethiopian and Oriental regions. Many animals, even within the historic period, have changed their habitat, though chiefly through human agency. There is often great irregularity in geographical distribution; thus, instead of finding the Dipnoi confined to one country or with a cosmopolitan distribution, we find one genus in Africa, one in South America, and one in Australia; the tapirs afford another example, one species living in the Oriental region, the rest in the Neotropical. Countries having very similar geographical positions and climatic conditions may have very different faunæ; we have already noted the difference in this respect between north and south Africa, although the two regions are equidistant from the equator; the same is true of India and northern Australia. We note further that the absence of any group of animals in a country does not necessarily imply that that country is unfavorable to the growth and development of such animals; thus rabbits, when introduced by man into New Zealand, found it so favorable an environment that they became a veritable pest through their increase in numbers. The gypsy moth and the English sparrow, introduced into North America, have found that country so favorable to their development that

they have become decidedly objectionable. Let us consider, then, some of the factors which affect the geographical distribution of animals.

Many of the smaller animals, such as Protozoa, are capable of passing into resting stages by inclosing themselves in cysts capable of resisting desiccation; they may thus be blown about by the winds and so obtain a universal distribution. Many small animals, such as worms, Crustacea, and Mollusca, may be carried about from place to place in the mud which adheres to the feet of wading birds. Animals of sufficient size and capable of free locomotion may migrate from place to place as the climatic conditions change or the necessity for more abundant food dictates. But the extent of such migration varies with the different animal types as hindrances to further advance arise. New natural enemies may be met in the new regions entered and so further progress arrested. The desert is an impassable barrier to the majority of animals; broad rivers are a barrier to such animals as the monkeys, which cannot swim; lakes and inland seas are usually obstructions to all but aerial types, and the same is true of lofty mountains. But what is to-day a barrier may not have been so in the past, and *vice versa*. Thus in the Pleistocene period the British Islands were a part of the continent of Europe, hence it is not surprising that the animals comprising the fauna of Great Britain are found likewise on the adjacent continent. The Isthmus of Panama was until recent times submerged beneath the ocean, and North and South America were separated from one another; the marine fauna on the two sides of the isthmus is identical, while the two continents have few animals in common. As animals have migrated so as to cover greater and greater areas, it was very natural that they should be rendered entirely extinct in some regions while still abundant in others; thus arose discontinuity in distribution, and it readily follows that the greater the discontinuity the longer must have been the period during which the group in question has occupied the earth. Thus we see that the Dipnoi must be a group of great antiquity.

Finally, the fauna of certain islands which have never been connected with the continents is interesting, such as the islands of volcanic origin in the midst of the Pacific. Here ocean cur-

rents are largely responsible for all but the aërial fauna. Many small animals may be carried for considerable distances on floating objects and eventually be cast up on some such island. The paucity of mammals on these islands is significant, the entire mammalian fauna being frequently restricted to a single species of bat and a mouse. Within recent years man has voluntarily and involuntarily, through commerce and colonization, greatly altered the natural distribution of animals. The reindeer and the bear were within historic time inhabitants of Great Britain. Horses and swine have been brought to North America from the Old World, and through the zeal of the hunter many valuable wild animals are rapidly approaching extinction.

# CHAPTER XII

## THEORETICAL BIOLOGY

In the preceding chapters, in which we have considered the more elementary facts of biology in general and of zoology in particular, we have from time to time noted matters of considerable theoretical interest. Many volumes have been written on these subjects, which constitute the philosophy of biology, and there has been as much diversity of opinion as there is on most philosophical subjects. It will be interesting to follow briefly the more important lines of reasoning which have been suggested by various thinkers from the time when the subject was first scientifically considered, at about the beginning of the nineteenth century, down to the present day.

As soon as scientists were sufficiently familiar with the structure of animals and plants to recognize that the species could be grouped into genera, the genera into families and so on, the questions arose: How did all the various organisms come into existence? Have there always been as many species on the earth as there are to-day, and will they remain the same for all time to come? Linnæus replied: There are as many species as an Infinite Being created in the beginning; or, to put it in other words, each species living to-day came into existence by a special act of creation when life first appeared on this earth. But when fossil remains were more carefully studied and as they became more and more numerous, it was soon apparent that in past ages the earth had very different inhabitants from the present. Scientists who held to the theory enunciated by Linnæus attempted to explain this fact by assuming that each geological period was, so to speak, complete in itself, and was suddenly brought to a close by some mighty convulsion or revolution of the forces of nature, a cataclysm, as it was called, which exter-

minated all life; then a new period began, and an entirely new set of animals and plants was created. There was, however, no evidence, either geological or theological, for any such cataclysms with attendant repetitions of creation, and geologists succeeded in showing that the forces which affected the form and structure of the earth in the past acted in much the same way that they do to-day. Thus there was gradually forced on the minds of many scientists the conviction that there must have been some real connection between the various types of organisms living in different ages, that the later animals and plants must represent the descendants of the earlier, from which they have been evolved as it were.

This theory of descent naturally met with strong opposition, and one of the first questions to be asked by its opponents was, How can so great variation from the original or primitive types have arisen? The French scientist, Lamarck, was one of the first to answer this question; in 1809 he published his theory that changes in animal species have been brought about through differences in the conditions under which animals live, in other words, through their environment, more especially as such differences involve the greater use or disuse of certain organs. Thus an organ would be increased or diminished in size, and this increase or diminution would be handed on to the offspring, which would inherit the characteristics of the parents and if living under the same conditions would accentuate them; thus in course of many generations there would be an accumulation of differences, which would result in a type of structure very different from the original stock. To give some concrete examples of how various structures would develop or disappear in accordance with this theory: the hoofs of such animals as the Ungulata would develop from numerous generations running on hard ground; the neck of the giraffe would lengthen from continually reaching after the shoots on the tree tops; the posterior appendages in the whales would be lost through the development of the tail fin and their consequent disuse; cave animals would become blind through the lack of use of their eyes.

That many organs in the body increase or diminish in size by use or disuse is a fact known to all; muscular development is a familiar example, but it will be noticed that Lamarck's

theory rests on the assumption that such variations are transmitted to the offspring, and ever since this theory was propounded, scientists have been arrayed in two bands, the one maintaining that such acquired characteristics can be transmitted to offspring, the other that they cannot; it is sufficient, perhaps, to say that, however well the theory may account for the development or the loss of various structures, it is extremely doubtful whether any reported example of an acquired characteristic being transmitted from the parent to the offspring has been proven conclusively to be so. This theory is of much interest, because to-day a minority of scientists adhere to it under the name of Neo-Lamarckism.

Thus many scientists came to recognize in the theory of descent or evolution the only explanation of the succession of plant and animal life on the earth, although it was not until the latter half of the century that evolution was accepted by all scientists and its principles employed in many other departments of knowledge as well; many theologians believe the real meaning of creation to be the institution of the order of nature, and hence do not hesitate to accept the evolutionary theory. But although there is universal belief in evolution, the manner in which it has been brought about is still a moot point.

Interest in the subject was reawakened in 1859 by Charles Darwin, an English scientist, when he published his theory of natural selection, a theory which commanded especial attention because based upon years of careful observation and experimentation. In order that an animal may in the course of generations give rise to descendants of a very different type it is necessary that there should be individual variation, and that this variation should be transmitted from parent to offspring; hence the center of interest in the search for the cause and method of evolution is the individual animal or plant, that is to say, the species, and so Darwin undertook to determine whether species are constant or whether it is probable that one may give rise to another. For it is perfectly evident that if new species may arise in this way, then the same process must give rise to new genera, families, orders, classes, and types; the evolution of the larger groups takes care of itself provided we can account for the evolution of the smallest.

Darwin made a special study of domesticated animals. It is a fact of common observation that no two animals are exactly alike, and that man by selecting desired points of variation can produce stocks in which these special points are developed to a remarkable degree. Thus by carefully selected variations the breeder has produced the many varieties of domestic cattle, horses, and fowls with which we are familiar. All these different breeds are considered varieties of one and the same species, and each, if kept isolated from other varieties, will in most cases breed true,

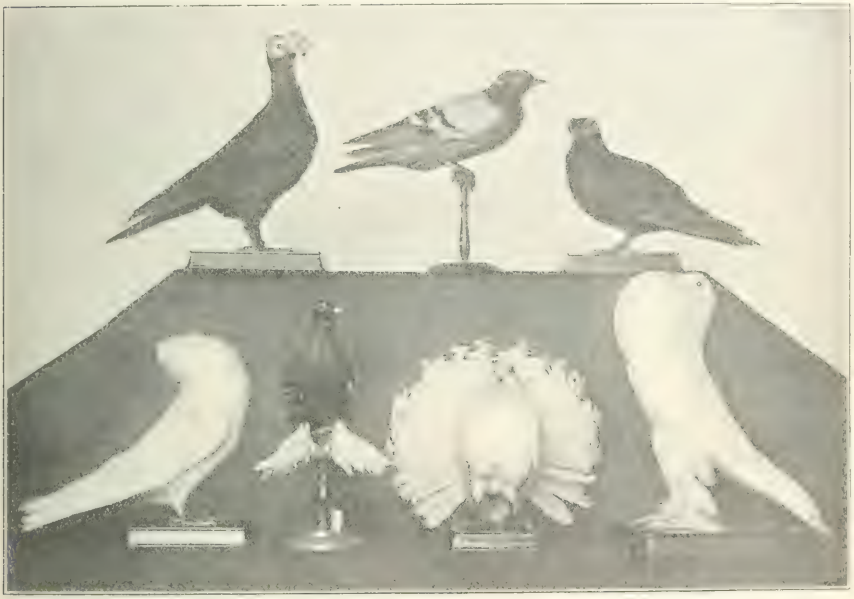


FIG. 419. *Columba livia*, several varieties, showing the great variation under domestication and artificial selection. (From a photograph provided by the American Museum of Natural History.)

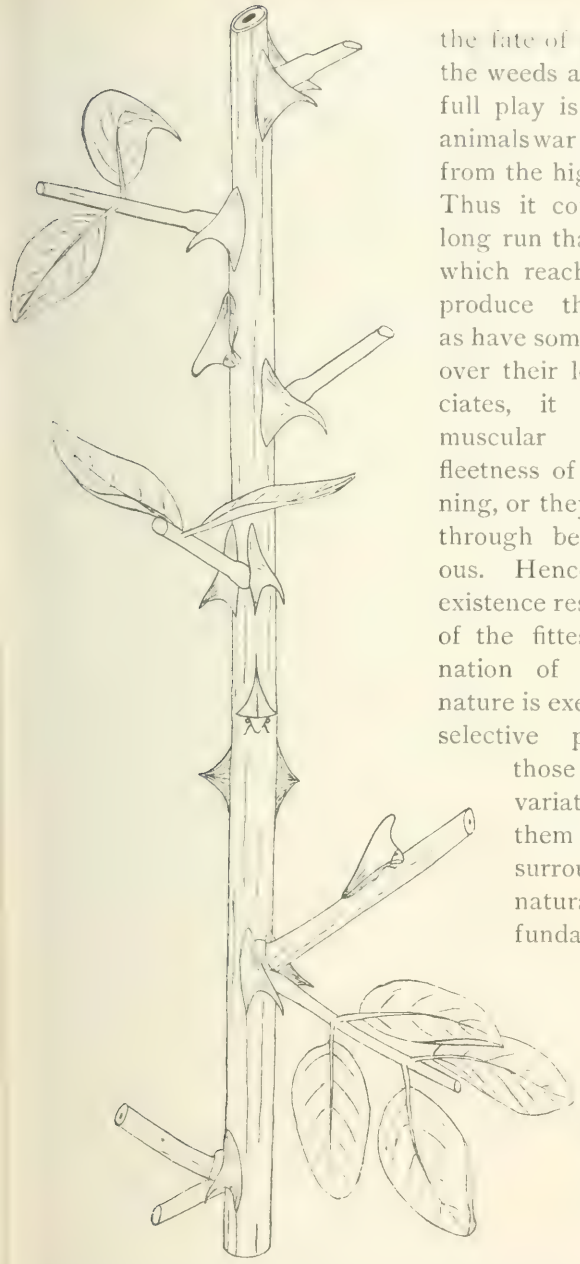
that is to say reproduce its kind with but slight variation; but if allowed to cross with other varieties, the distinctive characteristics of each tend to disappear and there is usually a reversion to the primitive ancestral type, a phenomenon known as atavism. Darwin's experiments with the domestic pigeon afford an instructive example. Fanciers recognize a large number of varieties in the pigeon, such as pouters, tumblers, carriers, and fantails, and these are so different from one another that

formerly scientists recognized them, not only as distinct species, but in some cases as belonging to different genera even (Fig. 419); the fantail has from thirty to forty-two tail quills, while other pigeons have only twelve or fourteen; the carrier has thirty-eight vertebræ, the pouter has forty-three. These differences and many others are most fundamental; but Darwin succeeded in showing, by careful crossing, that all these different types would revert to a type very similar to the wild rock pigeon, *Columba livia*, which must have been the ancestor of them all, and of which they are consequently merely so many varieties. Thus he demonstrated that species are not fixed, but that varie-

FIG. 420. *Phyllopteryx eques*, an Australian sea horse closely resembling in form and color the algæ amongst which it lives. (From Ludwig-Leunis' Synopsis der Thierkunde.)

ties are in reality incipient species, — species in the process of development, and in consequence species are incipient genera.

Now Darwin has undertaken to show that nature exercises a power of selection over wild animals similar to that exercised by man over the domestic animals, but acting much more slowly. He pointed out that many more plants and animals come into existence every year than can possibly find room and food enough on this earth. Many young animals are devoured by other animals, many are killed by storms or other unfavorable conditions, and even as the animal approaches adult life it still has many enemies. There is, then, a continual struggle for existence on the part of every animal and plant; plants are preyed upon by animals and in turn prey upon one another, –



the fate of a flower garden if the weeds are allowed to have full play is a good example; animals war against one another from the highest to the lowest. Thus it comes about in the long run that those organisms which reach maturity and reproduce themselves are such as have some special advantage over their less fortunate associates, it may be greater muscular strength, greater fleetness of foot, greater cunning, or they may even prevail through being less conspicuous. Hence this struggle for existence results in the survival of the fittest, and the elimination of the unfit. Thus nature is exercising a continual selective power, preserving those organisms whose variations best adapt them to life amidst their surroundings; this is natural selection, the fundamental proposition in Darwin's theory; he offers no explanation as to the origin of the variations which nature chooses, they are fortuitous.

FIG. 421. *Enchenopa.* Tree hoppers on a locust twig, showing their resemblance to the thorns; when at rest the body is depressed into contact with the twig as here represented —when walking it is raised as in Fig. 207 and the legs become more conspicuous. (Drawn from life by the author.)

Some of the most interesting facts in favor of the Darwinian theory are afforded by such phenomena as protective resemblance and mimicry. By protective resemblance is commonly understood any resemblance between an animal and its surroundings which tends to protect it from its enemies. Many pelagic aquatic animals are so perfectly transparent and colorless as to be well-nigh indistinguishable from the surrounding water. Many marine animals resemble seaweed in form and color; a notable example is a species of sea horse, which has curiously shaped filamentous outgrowths on the body, giving it a very ragged appearance (Fig. 420). Many tropical animals are striped or spotted, and so resemble the shadows cast by the surrounding foliage as the sunlight streams through it. The insects furnish many striking examples of this protective resemblance (Fig. 421); the walking stick (Fig. 422) and the leaf insect (Fig. 423) are very like twigs and green leaves respectively; the dead-leaf butterfly, *Kallima paralecta*, of the East Indies, presents the most perfect resemblance to a dead leaf, when it alights and folds its wings; another butterfly of the genus *Siderone* is very

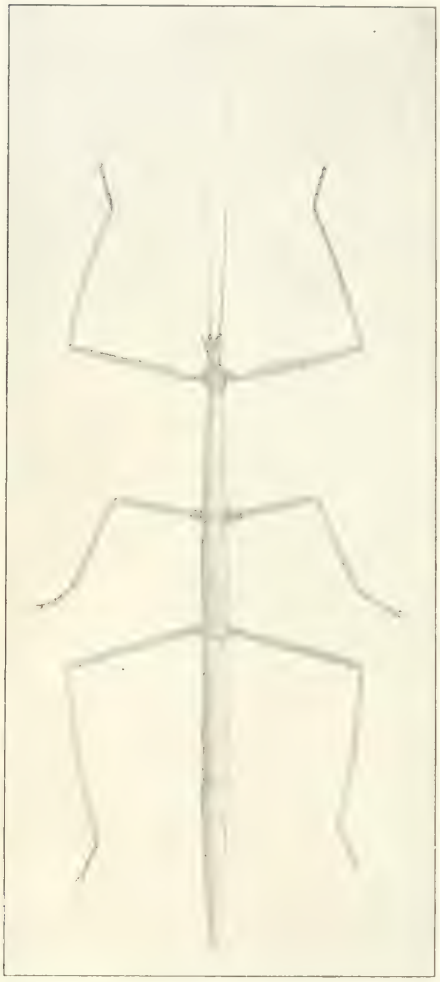


FIG. 422. *Diapheromera femorata*, ♀, the common walking stick of the United States; natural size. (Drawn from specimen.)

similar to *Kallima*. Animals living on the snow as in the Arctic regions are often white; the polar bear and arctic fox are familiar examples; some change their colors, being dark in summer and white in winter. Desert animals are often yellowish; many fishes are the same color as the bottom upon which they lie or the plants and animals amongst which they swim.

When one animal which is practically defenseless resembles another which has some marked means of protecting itself, the phenomenon is known as mimicry; this term is not intended to imply that there is any conscious imitation on the part of the more helpless animal. The insects, again, supply some of the best examples of mimicry. The humming-bird moth, *Maroglossa titan*, so closely resembles a humming bird in shape and color that it has frequently been shot by hunters, but its resemblance to the bird serves to protect it from various insectivorous birds to which it might otherwise fall a prey. In the same way a harmless beetle, *Coloborhombus fasciatipennis*, of Borneo, is protected by its close resemblance to a large black wasp, *Mygnimia aviculus* (Fig. 424). Some species of butterflies are much disliked by birds because they are bad-tasting and so they are unmolested; certain other butterflies which are perfectly palatable to birds are protected by their striking resemblance to these objectionable species. The common reddish brown monarch butterfly, *Anosia plexippus*, of North America, is one of these distasteful species; the viceroy butterfly, *Basilarchia archippus*, closely resembles it in color and markings, but is not distasteful to birds. Another

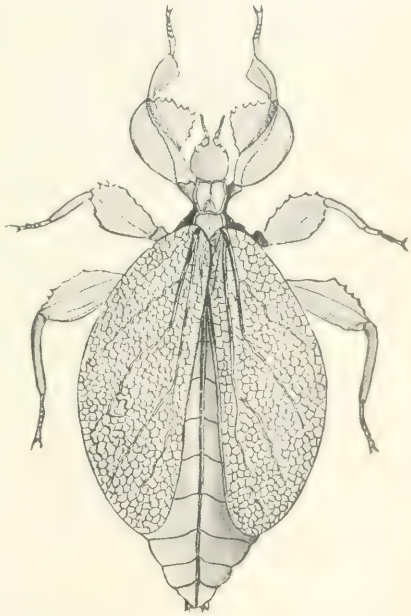


FIG. 423. *Phyllium siccifolium*, the leaf insect. (From Brehm's Thierleben.)

example is the butterfly *Methona psidii*, which is imitated by the butterfly *Leptalis orise* (Fig. 425). Some moths closely resemble wasps, the wings being perfectly transparent. Among vertebrates some perfectly harmless snakes mimic poisonous species, and in the East Indies harmless and helpless birds are known which resemble certain powerful species. It is an essential condition of all mimicry that the two species which resemble each other should have the same habitat in order that the resemblance may be protective.

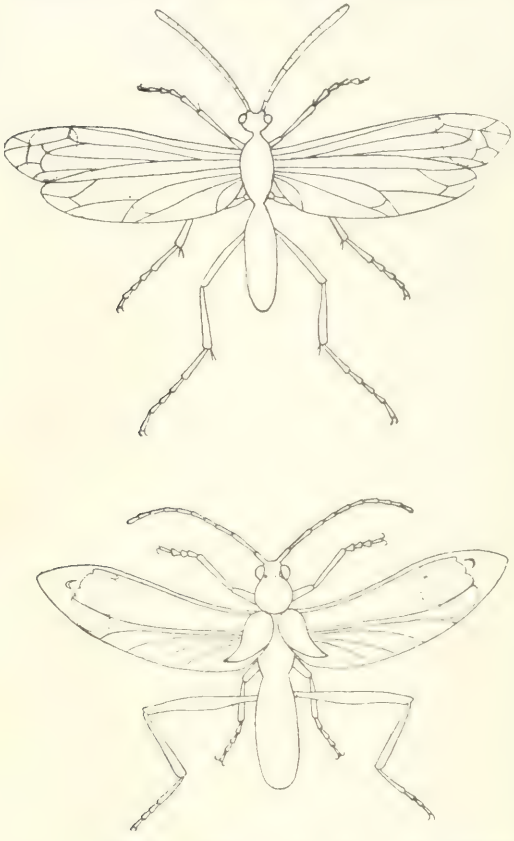


FIG. 424. *Mygnimia aviculus*, upper figure, a wasp imitated by a beetle, *Coloborhombus fasciatipennis*, the lower figure; both insects are black with large white spots (indicated by dotted lines) near the tips of the wings. (Alfred Wallace.)

It will be readily seen what an important rôle such protective resemblances must play in the struggle for existence, and how natural selection may well account for their permanence. There is one other aspect of Darwin's theory which we must mention. It may happen that certain structures which have long been carefully preserved by natural selection are no longer necessary for the vigorous maintenance of the species; natural enemies may have disappeared, food may have become much more abundant. The result would be that many more individuals would reach maturity than before; there would be free crossing

between individuals possessing the selected characteristics and those in which they were absent or imperfectly developed, and thus they would gradually tend to disappear. This result has been brought about by a sort of cessation of natural selection, and the process is known technically as panmixia. We may

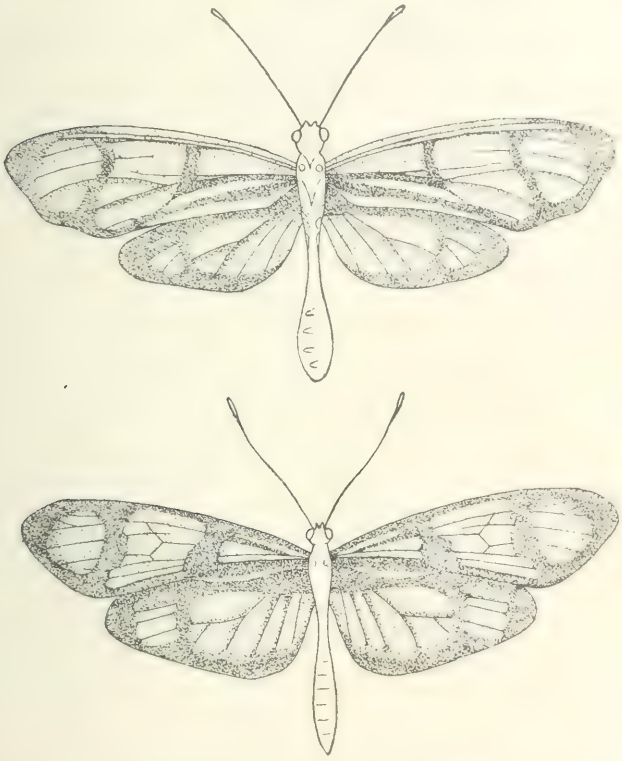


FIG. 425. *Methona psidii*, upper figure, a butterfly distasteful to birds, imitated by *Leptalis orise*, the lower figure. (After Wallace.)

note as an illustration of this process an example already considered as illustrating Lamarck's theory of use and disuse, thus showing how the two theories account for the same phenomenon. As the ancestral Cetacea sought the land from time to time, posterior appendages were an advantage to them; but as they became entirely aquatic, such structures were not only useless but a positive hindrance to locomotion, and so interfered with many of the functions of life. Hence individuals which ex-

hibited the variation of having these appendages less developed than their fellows possessed an advantage; natural selection thus resulted in a gradual diminution in the size of the pelvic limbs until they became entirely lost. In the bodies of nearly all animals there are many rudimentary structures which are undergoing the action of panmixia; some seventy such structures have been noted in the human body, which one scientist describes as a "museum of relics"; they serve to show something of the past history of the organism, just as the silent letters in many words reveal the history of such words.

The theory of natural selection as accounting for the origin of species is probably accepted to-day by the majority of scientists, although not a few regard it as inadequate, believing that there are still other principles affecting the origin of species which have not as yet been discovered. Some important objections have been raised to the theory, which demand attention. It has been said that the variations which occur in nature are far too slight to give rise to differences of structure sufficiently great to produce new species. This is an objection of some weight, and yet there are instances which tend to show that under certain circumstances at least it is not valid. An interesting example is furnished by a litter of European rabbits which was placed early in the fifteenth century on the island of Porto Santo. They have multiplied rapidly and have become so altered in structure, color, and habit as to constitute a new species, different from the European rabbit, with which they will no longer interbreed. Here natural selection had full play, but under the condition of isolation, the rabbits being separated from the rest of their species; and this factor is of great importance in all theories of evolution.

Another important objection is that there is nothing in nature to prevent free crossing between the various members of a species, and any variation would thus be promptly obliterated through crossing with individuals which did not possess it. We know that domesticated varieties will not breed true if allowed to cross with other varieties. An extension of the factor of isolation just referred to has been brought forward to meet this objection, and is sometimes called the migration theory. As the number of individuals of a given species increases there

is a tendency for them to occupy a more and more extended territory; some may even take to active migration into regions where a greater food supply renders the struggle for existence less severe, and thus the component individuals of the species become separated into groups more or less completely isolated from one another geographically. Or natural barriers may arise through geological processes dividing a species into two or more groups, which would thus be cut off from all communication with one another. At times some members of a species may be passively carried from one place to another, as on drifting logs or in the case of some animals on the feet of birds. But in all these various methods of distribution the ultimate result is that some members of a species are isolated from the rest; then natural selection can effect the development of desirable variations and a new species be produced just as in the case of the rabbits of Porto Santo already referred to. The fauna of many isolated islands confirm this theory. While, however, it is undoubtedly true that new species may arise in this way, yet we are by no means sure that it is the only or even the most usual method of species formation.

We have then two theories of descent: the Lamarckian, which attributes the origin of variation to the influence of the environment of the organism, — just how it does not say, — and develops new species through the use and disuse of parts; and the Darwinian, which does not attempt to account for variation, but merely speaks of it as spontaneous, fortuitous, and accounts for the formation of new species chiefly through the process of natural selection governed by the struggle for existence. It will be noted, then, that we have no definite theory, up to this point, of the origin of variation. A considerable advance was made in the field of theoretical biology by the German scientist, Weismann, in a series of essays on heredity beginning in 1883. Without going into the details of his theories here, we may briefly note one or two points concerning the origin of variations. Nearly all animals develop from a single cell which is formed by the very intimate fusion of two cells, the ovum and the spermatozoön, which have developed in two individuals, the female and the male; these two individuals differ, not only sexually, but in many other characteristics as well. Now the ovum

and the spermatozoön, which consist of germ plasm, are held to contain potentially all the characteristics of the female and the male respectively, except such as are due to the use or disuse of parts by the individual. In all the fundamental characteristics of the species the two kinds of germ plasm, male and female, are alike; hence the single individual which results from their fusion will possess these characteristics: but the combination of the characteristics which differed in the two parents may give rise to very different characteristics in the offspring. Thus variations may arise upon which natural selection then proceeds to act.

In the foregoing paragraphs we have epitomized the principal theories which treat of the method in which the evolution or descent of the existing organic world has been brought about, and have referred but briefly to the reasons which go to maintain a belief in the theory of evolution itself. We may now note some of the more important facts which bear upon this subject.

The most striking evidence in favor of the theory of evolution is palæontological and morphological. Much of the palæontological evidence has been noted in a preceding chapter. The various classes of animals did not all appear on the earth at the same time, but in succession from the lower to the higher at intervals of almost inconceivable length; there is no direct evidence of this in the case of many invertebrate classes, but this is due to the fact that the great mass of the oldest sedimentary rocks have been so metamorphosed, so altered in structure, that all fossil remains which they may have contained, have disappeared. Again, in the vertebrate classes there is a break in the order of succession; the Mammalia appear in the Triassic, while the Aves are first found in the next later period, the Jurassic. Now morphological evidence shows that the Aves and the Mammalia have both developed from the Reptilia; they are both highly specialized types, so that it is a matter of no importance which appeared first. On the other hand, we must remember that of all the vertebrate classes the birds are the least likely to be preserved as fossils, so that, although no remains have been discovered earlier than the Jurassic, it is by no means impossible that they may have existed earlier. The incompleteness of the geological record and the numerous factors which tend to prevent the formation of fossils have already been pointed out;

nevertheless in a number of cases it has been possible to trace the actual descent of living types or of particular organs from prehistoric ancestors; the evolution of the horse, already described, is a striking example, and the development of other Ungulata has been worked out in a similar way. The descent of certain types of the Gastropoda has likewise been determined with great completeness, but for the invertebrates in general direct evidence in palæontology of evolution is rare, since in the earliest fossiliferous formations the larger groups of invertebrates are already well developed, as we have noted. A further important argument supplied by the palæontological record lies in the fact that the earlier representatives of a type are much more generalized in structure than the later; high degrees of specialization which would arise through evolution do not appear until the type has existed for a considerable time. The older fossil fishes and reptiles had the vertebral column cartilaginous or only incompletely ossified. The structure and shape of the skull in most of the older fossil reptiles and mammals were like embryonic stages in those groups to-day.

The morphological evidence in favor of evolution is in part anatomical and in part embryological. A distinguished German scientist has said, "For the reflecting naturalist the facts of morphology are a single great inductive proof in favor of the theory of descent." The classification of animals is based on morphological resemblances; we distinguish a number of different kinds of animals, that is to say species, which do not usually interbreed; they are, however, in many cases connected with one another by numerous varieties. Species can be grouped into genera, they into families, and so on to the largest groups; and in very many cases, as we have noticed in the second part of this book, there are intermediate individuals or groups which form connecting links as it were between them, even the largest groups, the types, not excepted. And it is further possible to arrange the various groups of animals more or less like a genealogical tree, the simplest animals at the root and above them branch after branch of greater and greater complexity of differentiation given off as we ascend. That such a rational arrangement is possible is a strong argument in favor of the theory of descent.

In many groups of animals we find structures which have very different functions but are all constructed on a common plan or type which has undergone the most varied modifications. Thus the front legs of the frog and of the leather-back turtle, the wings of the bird and of the bat, the flippers of the seal and of the whale, the fore leg of the ox and the arm of a man, are all built on the same plan of skeletal structure. The parts of the vertebrate brain are essentially the same in all classes, but the degree of differentiation which is found in the higher mammals over the structure of the brain of a fish is almost inconceivably great. Such facts as these, which demonstrate a common type with manifold variations, point strongly to a common descent.

Still another argument for the theory of evolution is furnished by anatomy in the presence of numerous structures, especially in the higher animals, which are of no apparent use to the individual; they are very rudimentary as compared with the corresponding structures in lower animals where they are actively functional. We note, as a few examples, the minute hind limbs present in the python; the very rudimentary and useless wings of the Apteryx, a bird of New Zealand; the rudimentary wings of many beetles and other insects; the blind eyes of cave animals; and of the numerous rudimentary structures in man we may mention the minute tail, which never pierces the skin, the hair of the general surface of the body, and the vermiform appendix, which has not only become useless but even dangerous. We have already referred to such structures in connection with the Darwinian theory. Their presence is readily comprehensible on the theory of evolution, but unintelligible otherwise.

Sexual dimorphism, so highly developed in many groups of animals and very conspicuous among some birds and mammals, where the two sexes are often so different as to suggest their belonging to different species or even genera, affords an excellent example of evolution, each sex having developed along lines which best adapt it to its special activities.

Embryology furnishes numerous facts which indicate the correctness of the theory of evolution. The simplest form of animal life is a single cell; then we find a colony of nearly similar

cells forming a sphere; slightly higher up an individual consists of a sac whose wall is made up of two layers of cells. Now all animals above the Protozoa pass through these three stages in the course of their development: first the single cell, the fertilized ovum; then the sphere of cells of which the blastula is a type; then the two-layered sac represented by the gastrula. In other words, each individual in its earlier development passes through stages represented by the simplest animals. The embryos of the various classes of vertebrates so closely resemble each other at a very early stage of development that it is well-nigh impossible to tell them apart; young Mammalia cannot be distinguished from one another. All the vertebrates at early stages of development are strikingly like embryonic fishes in structure; like them they have gill slits and the corresponding structure of heart and arrangement of blood vessels; as development goes on, the special characteristics of each class appear. In the case of the birds and the mammals certain amphibian and reptilian characteristics succeed one another; finally the distinctive structures of the bird and the mammal appear, and the peculiar features of the order, family, genus, and species develop. Thus in the development of the higher animals there is a tendency to repeat stages common to lower groups, a fact which strongly indicates a descent from such ancestral types. All intermediate steps are not necessarily represented, but the general rule holds good and constitutes what the German scientist, Haeckel, has called the biogenetic law, that ontogeny is a recapitulation of phylogeny: in other words, that the development of the individual is a repetition of the development of the race.

Embryology furnishes still further evidence for evolution in the presence of numerous rudimentary structures which never appear in adult life. Thus teeth are found in some embryonic turtles, although they occur in no adult Chelonia. Some birds, such as parrots, have teeth in the embryo, although no adult living bird has teeth. The embryos of the whalebone whales likewise have teeth, although none are present in the adult. These facts all point to the conclusion that such types have descended from ancestors in which teeth were functional.

One other instance of embryological evidence is of interest,

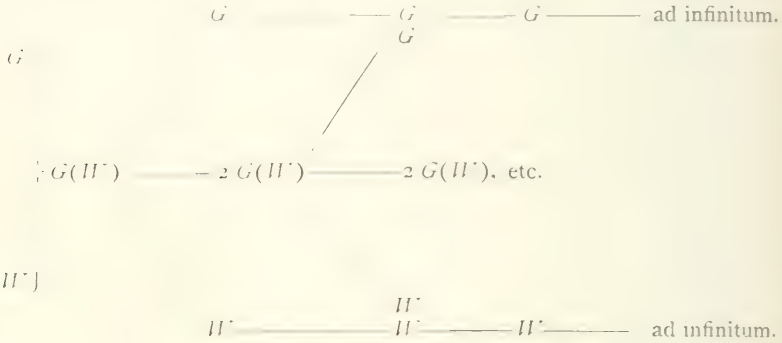
it lies in what may be called retrograde metamorphosis, of which some of the Crustacea furnish excellent examples. There the adult in some parasitic species of Copepoda and Cirripedia has become very degenerate in structure; the usual crustacean appendages are almost entirely lacking; eyes and other sense organs are absent, and the body is little more than a swollen sac capable of absorbing nutriment and of forming germ-cells. Yet these animals pass through the usual larval stage common to the majority of the Crustacea, provided with jointed appendages and with eyes and other sense organs. Thus the adult is clearly descended from ancestral species in which such structures were present and functional, while in its present parasitic mode of life they are no longer required.

There is another subject in the field of the philosophy of biology which has occasioned much discussion and has been the direct outcome of the various theories advanced to explain the action of evolution; this is the problem of heredity, which demands a brief notice here. Heredity has been defined as "the organic relation between successive generations." It is a truism that like tends to beget like. We are not surprised that in non-sexual reproduction the new individuals formed are like the parent in all essential respects, for here the offspring are manifestly directly continuous with the parent; they are portions of it which may or may not become separated from it; any variation under such conditions could not be accounted for. This is well illustrated by plants which reproduce by runners or can be made to develop from cuttings or grafts; by animals which reproduce through simple division, as in the Protozoa, or through budding, as in many sponges and Cnidaria, some flatworms, all the Bryozoa, some jointed worms, and many of the Tunicata. In sexual reproduction, too, like tends to beget like so far as the more fundamental characteristics of the species are concerned, but the offspring may exhibit qualities which have come not from the parents but from more remote ancestors; such instances of atavism, the recurrence of more or less remote ancestral traits, are not uncommon, especially among domesticated plants and animals. Every one knows that most cultivated fruits will not produce their kind from seeds, which are the result of sexual processes, but only from cuttings, grafts, or

buds, which develop non-sexually; the seeds on the other hand usually give rise to fruits like the wild varieties from which they originally arose. Among animals we may note the tendency of domestic pigeons to revert to the ancestral blue rock pigeon; horses occasionally exhibit stripes like those of their wild ancestors.

The great advances which have recently been made in our knowledge of heredity have been through the application of Mendel's law, so named from its discoverer. The details of this law are too complicated for elementary treatment, but the fundamental principle is simple, — it is the law of the "purity of the germ-cells." A simple concrete example will serve in illustration. Let us take two animals of the same species, which differ in some one striking characteristic, such as color in the gray mouse and the white, albino mouse; crossed with one another they will produce offspring all of which will be gray, hence the gray characteristic is said to be "dominant," the white, "recessive." Now the germ-cells which these gray mice of the second generation produce will bear the gray characteristic or the white, and the two in equal numbers, but no germ-cell will have both characteristics; this is the principle of the purity of the germ-cells and we see its effect in the next generation, for the gray mice of the second generation, when bred with one another, will give rise to the third generation which will consist of both gray mice and white mice in the proportion of three to one. These white mice, if bred together, will produce only white offspring for all subsequent generations. These gray mice, although all apparently alike, are really of two kinds; one third will produce only gray mice forever, but the other two thirds are precisely like the gray mice of the second generation, and like them will produce both gray and white offspring in the proportion of three to one. The reason for this is simple. The gray mice of the second generation possess germ-cells, half of which have gray characteristics and half white, — to represent it graphically, $G + W$; the crossing of two such individuals affords the following possible combinations, $GG + 2GW + WW$. The combination $GG$ will naturally be gray and can produce only gray offspring; the same law is true for the combination $WW$; but in the combination $GW$, the $W$ is

recessive as we saw in the second generation, and hence these mice will all be gray, but will produce gray and white offspring in the proportion of three to one; since in the combination $GW$ the $W$ is recessive, it is best written $G(W)$. This whole matter may be represented graphically as follows: —




Such is Mendel's law of the purity of the germ-cells manifested through dominant and recessive characteristics; it involves in addition many complications, as when two individuals differ in more than one characteristic and also when the first crossing results in individuals different from either parent, as sometimes occurs. These matters will be found considered at length in extended treatises on the subject.

But the chief interest in the subject of heredity centers in the characteristics which may be transmitted from the parent to the offspring; can the offspring inherit characters which the parent may have acquired in the course of its existence through the use or disuse of its various organs or through the direct action of its environment, such as climate, food supply, and the struggle with enemies? In considering acquired characters we should exclude mutilations, since these are brought about by temporary not continued influences, and there is no authentic evidence that they are ever inherited. Chinese women are not born with deformed feet; the Flathead Indians are not born with deformed skulls; the Jews are not born circumcised more frequently than the Gentiles. A considerable number of living biologists have pointed out the remarkable isolation, we may even say insulation, of the germ-cells from the somatic cells.

In the embryology of many animals it is possible to follow the development of the germ-cells of the adult directly from the original germ-cell, the fertilized ovum. The somatic cells develop from it, but a part, destined to become the germ-cells of the adult, is unaltered by the development of the body about it. There is thus a direct continuity of germ substance, of germ plasm from parent to offspring, from the very beginning of the race. Hence it is not surprising that the fundamental characteristics of the species are inherited from generation to generation.

But in order that there may be any evolution there must be an inheritance of variations; these may lie either in the germ-cells themselves, as expressed in Weismann's theory, or they may be derived from the parent through the use of its various organs. It is extremely difficult to get any evidence of fact which shall speak conclusively for the one supposition or the other. It is very necessary, too, to distinguish between a real inheritance and the reappearance of characters which may be due merely to similar conditions of life. Many biologists believe, with Weismann, that there is absolutely no inheritance of acquired characters; many believe, with Lamarck, that evolution is brought about only by the inheritance of acquired characters; and many are inclined to take the middle course, which was also held by Darwin, that while natural selection is the primary factor in evolution, there may be an inheritance of characters acquired during the life of the individual.

Theories have been suggested to account for the way in which the somatic cells must affect the germ-cells if acquired characters are to be inherited, but none of them has found any general acceptance among scientists, since they have had no facts of weight behind them. Darwin's own theory of pangenesis, which he qualified as provisional, assumed the transmission of minute particles, which he called gemmules, from every cell in the organism to the germ-cells, which were thus able to bear them as an inheritance to the offspring, where they developed into the same kind of cells as existed in the parent; there is no evidence that such gemmules exist, and many facts are against their existence; to-day the theory is chiefly of historic interest. That the removal or lack of development of the germ-cells often

has a very noticeable effect on the rest of the body has long been known, and animals have often been spayed or castrated to bring about certain modifications. But in what way this influence is produced is absolutely unknown, and so we have no reason to assert that characters acquired by the somatic cells cannot affect the germ-cells merely because we know no way of bringing this about. In any case it is extremely probable that the general nutrition of the body should affect the germ-cells as well as the somatic cells, and we have in fact some evidence that a lack of proper nutrition tends to the production of offspring of a more atavistic type.

Every germ-cell must be conceived of, however, as containing, potentially at least, the energy necessary for bringing about the various changes incident to development. But the actual structure of the germ-cell does not differ materially from that of many other cells in the body. Just as in cell division the nucleus assumes the prominent rôle, so in the germ-cell the nucleus appears to be the more important part of the cell, and certain experiments tend to show that it is a prominent factor in heredity. Thus a sea-urchin egg may be broken up, and a portion of the cytoplasm, which contains no part of the nucleus, allowed to unite with a spermatozoön from another species of sea-urchin. An embryo results, which possesses the characteristics of the species from which the spermatozoön came.

Concerning the whole matter of the inheritance of acquired characters, the most that we can safely say is, that nothing is proven either for or against it; a more comprehensive study of facts which bear on this subject is much to be desired.

As yet we have said nothing directly concerning the origin of man. We have shown, however, zoölogically that he is an animal of the order Primates, suborder Anthropoidea, and closely related structurally to the higher apes; and palæontologically we have noted a still closer relationship through the intermediate type, *Pithecanthropos erectus*, of Java. The very general belief among scientists to-day is to the effect that man has developed by a natural process of evolution from a type common to him and the higher apes; these differ too much from one another and from man in certain details to admit of any existing genus being considered the ancestor of man. But

man is most conspicuous because of his intellectual and social development; these characteristics, too, have in all probability attained their present height through a process of natural evolution. At the beginning of man's descent, cunning probably played the most important rôle in natural selection. Then we have the living together in families and communities, and the building of habitations, all of which exist among some of the higher apes to-day, and in a condition only a degree more advanced among certain savage tribes of men. From this stage man rapidly becomes altruistic; the sense of justice and of honor are naturally evolved, and step by step we reach the highest type of civilized man as he exists to-day with all his social, scientific, and artistic faculties. To gain some realization of the extent of man's development, we have but to compare the Australian bushman with the best type of civilized European.

# CHAPTER XIII

## ANIMAL BEHAVIOR

In preceding chapters we have touched upon many aspects of the behavior of animals in their general relation to their surroundings, and also under such special conditions as commensalism, symbiosis, and parasitism. Since this subject is receiving considerable attention from scientists to-day, we may consider briefly a few further aspects of it here. We shall, in general, note the behavior of the animal as a whole rather than of its various organs and tissues, using the term in a broad sense to indicate responses to the various stimuli which the animal may be subjected to. Behavior may be either conscious or unconscious, but, with this use of the term, consciousness is not necessarily implied or excluded; we shall, however, endeavor to ascertain how far consciousness is present in animal activities.

An emulsion of oil and water, as seen under the microscope, exhibits streaming movements, and behaves precisely like living protoplasm under similar conditions; the emulsion is not conscious of its behavior; is the protoplasm? The solution of this problem is difficult. We do not hesitate to explain the behavior of lifeless matter by purely physical or chemical laws, or to admit that it depends on similar laws not yet discovered. But in dealing with living matter we are inclined to attribute to it the same sensations and emotions which we ourselves experience in our complex, conscious behavior, even though there may be much simpler explanations. Thus some scientists have gone so far as to attribute to some of the Protozoa such characteristics as perception, choice, volition, memory, and fear, and the superficial study of the activities of these simple animals might well lead to such a conclusion.

Let us examine a number of free-swimming Ciliata in a drop

of water under the microscope; introduce into their midst a bit of food substance, and they rapidly collect around it. Their behavior appears to exhibit marked intelligence until we experiment further and find that we may introduce a non-nutritive body, such as a bit of paper, and they will collect about it in precisely the same way. Note the manner in which many Ciliata sweep the food into their mouths by their rapidly vibrating cilia; they exercise no choice in the substances swallowed, anything which may be carried along in the current of water passes in, whether nutritive or not, grains of carmine as readily as food. Extended experiments on the Protozoa tend to show that they do not profit by experience, and lead us to believe that in these simplest animals consciousness is extremely improbable; although their behavior is often very complex, it is probably in all cases merely a direct response to the stimuli, often themselves complex, of their environment, and hence may eventually be shown to be explicable by physical and chemical laws.

Let us look at some of the activities of somewhat more complex organisms. The leaf of the Venus' flytrap closes on the insect which alights on its surface, pours out digestive fluids and absorbs the insect. The tentacles of the sea anemone or the coral polyp contract over a bit of food which comes to rest on its oral disc and force it into the mouth. In both these instances we have complex reactions to a certain stimulus, but most scientists would hesitate to attribute consciousness as the term is commonly understood to the plant leaf, and the reaction of the polyp is very similar; each is a direct response to a given stimulus, which passes directly to the parts which respond: it is not even as complicated as a reflex action, which can only occur when both afferent and efferent nerves as well as a nerve center have been established. The plant has no nerves and the transmission of the stimulus from cell to cell must take place through their protoplasmic continuity; the polyp has nervous tissue, but of so diffuse a structure that stimuli pass directly from the part affected to the part which reacts.

Why there are responses to various stimuli is a question we cannot yet answer, any more than we can tell why certain chemical elements will combine with some substances and not with others. The hen's egg, when laid, consists largely of lifeless substances

and a few living, microscopic cells; if placed under the proper conditions these cells, in the course of three weeks, will have increased in number, absorbed the lifeless matter about them and shaped themselves into tissues and organs, nerves, bones, muscles, etc.; we may say that the cells know how to do this, but we do not mean that they possess intelligence in the sense that man possesses it any more than we should ascribe intelligence to the minute particles of quartz, which select other particles of the same nature and unite with them until they have built up the perfect quartz crystal.

Passing from the simple reactions of single cells as in the Protozoa to the simple coördinated actions of groups of cells as in the sea anemone, we may take as the next step in the evolution of animal behavior, the simple reflex action; this involves a much higher degree of anatomical differentiation. In this process there is required a sensory organ, an afferent nerve which shall transmit the stimulus from the sensory surface to a nerve center, and an efferent nerve to transmit the impulse from the nerve center to the organ which responds. The process thus becomes of considerable complexity, and we scarcely know enough about animal behavior in its details to determine how it may have arisen from the simple direct responses of the lowest animals. It is distinctively an involuntary process, and yet, in its more complex manifestations, may exhibit purposive phenomena. Thus if we take a recently decapitated frog and put a drop of acid on the thigh, the foot will be drawn up and attempt to rub the acid off; if the foot be held so that it cannot move, the foot of the other leg will attempt to remove the acid; yet the decapitated frog if left to itself exhibits no voluntary movements, and without spontaneous movements we cannot attribute intelligence to the organism; can we go a step further and say that consciousness is likewise absent from the reflex action? Effective consciousness certainly is absent, — it is precluded by the involuntary nature of the phenomenon; on the other hand, we can conceive of a momentary consciousness present during the activity of the nerve center, not effective to alter the response, — a simple accompaniment of the reflex act, — called into existence by the stimulus and immediately disappearing. Taking such a rudimentary type of consciousness as a starting-

point we can readily conceive of its evolution into effectiveness through more and more complex differentiations of the reflex act, until we have reached its highest manifestations in our own consciousness and in that which we assume to exist in the higher animals. If this momentary consciousness whose presence we may assume in reflex processes has any precursor in the simple direct responses of the lower animals, it must lie in a hypothetical sentience inherent in living protoplasm and equally ineffective; beyond this point the question is one for the metaphysician rather than the natural scientist.

From reflex processes we pass with little difficulty to instinctive actions, in fact there is at times some difficulty in drawing a sharp line between these two forms of behavior. The term *instinct* is used pretty loosely both in popular and scientific discussions, and different scientists have given rather divergent definitions of it; according to one of the most epitomized definitions instinct is compound reflex action, but a little more accurate conception of it may be obtained by considering its characteristics more fully. Behavior is said to be instinctive which consists of complex, coördinated actions performed by the animal without any previous experience and independent of instruction; performed in essentially the same manner by all the individuals of the same sex and race; and tending towards the well-being and preservation of the individual or the race, -- that is to say, having some ultimately utilitarian end of which the individual may be, and probably usually is, ignorant. From this definition we see that an act may not be wholly instinctive but once, since after its first performance the animal has had experience, which may modify its subsequent acts, and in fact instinct is very early modified by experience. We note, too, that instinct is directed towards two ends, either the well-being of the individual or of the race, the former relating to the nutrition, development, and protection of the animal, the latter to reproduction and such allied phenomena as nest-building, care of the young, and social organization. Instincts, then, from the nature of our definition must be conceived to be inherited characteristics.

The chick walks about shortly after emerging from the shell; the coördination of muscular movements is instinctive. It pecks at first at anything which attracts its attention; the pecking is

instinctive, no choice is exercised between nutritious and non-nutritious substances; the ability to distinguish is acquired through experience. Flying is instinctive with insects and with some birds. Swimming and diving are instincts with waterfowl. The red-winged blackbird builds its nest in marshy places, often on branches overhanging the water, and the young not infrequently fall into the water before they can fly; when this accident occurs they at once inflate themselves and thus readily keep afloat. The cowbird lays her eggs in the nests of other birds; on hatching, the young cowbird is frequently much more developed than the rightful inhabitants of the nest, and has been observed to lift and push them out so that they are left to die while the cowbird remains in sole possession. In these instances there is no possibility of previous instruction or experience, factors which we must always eliminate from purely instinctive actions. Some wasps sting certain other insects, such as bees, flies, and beetles, in such a way as to paralyze them without killing them, and then place them in their nests beside their eggs and seal them up to serve as food for the young when they shall have hatched. It is often quoted as a remarkable example of instinct that the wasp knows just where to sting its prey and render it helpless without killing it, but more careful observations have shown that the prey is by no means always stung in the same place but in a variety of places, and that after being sealed up in the nest, many die, and the developing wasps appear to thrive as well on the dead as on the living. The acts of stinging and of the storing up in the nest are, however, acts of pure instinct, and the latter is of considerable complexity. Fear is often spoken of as an instinct; there is much evidence, however, to show that it is due to experience. Many young animals exhibit no fear at the first sight of man; young birds are frightened at the first approach of a hawk, but they are equally afraid of a harmless sheet of flying paper.

We may now inquire what part consciousness plays in instinctive behavior. It seems to be pretty generally agreed by writers on this subject that consciousness is present to a greater or less extent, and instinct has even been defined as conscious reflex action. We have already noted that it is only the first performance of an automatic act that can really be called instinctive,

since in its repetition it may be modified by experience, this would be impossible if consciousness were not present, — in fact the ability to profit by experience may be taken as a criterion of effective consciousness. Another aspect of instinctive behavior tends to confirm the presence of consciousness. In many cases the external stimulus which may give rise to a certain instinctive act is very obscure or appears too insignificant to awaken a response. There seems to be a stronger impulse to the act from within; thus the taking of food may be due more directly to a need for nutriment felt within the body than to the sight of food; and further, in many instinctive acts, the external stimulus appears to serve merely to arouse the stronger impulse from within which gives rise to the instinctive response. It has, in fact, been pointed out that the presence of a "felt need" within the body may afford a distinction between the instinctive act and the reflex action.

When we come to consider the origin of instinct we find two theories in existence, each of which has numerous adherents. According to one theory instincts are inherited habits; according to the other they have been evolved through the natural selection of the fittest methods of automatic response, that is to say, of reflex action; this second theory is probably the more widely accepted. Thus we see that thinkers on this subject ascribe to the evolution of organic behavior the same principles as to the evolution of organic structure, with the result that the same phenomena are accounted for in two quite different ways. The first theory assumes that these instinctive acts have been acquired by the individual through repeated experimentation, observation, and reflection until they have become automatic, that is to say, habitual, and then these acquired habits are inherited by the offspring and appear in them as instincts, which do not have to be learned, although, it is said, they may be forgotten. Unfortunately there are no very reliable facts in support of this theory of the transmissibility of acquired knowledge from parent to offspring, unless we give to the term *instinct* a much broader significance than it usually receives in scientific discussion. The second theory is the pure application of natural selection through the survival of the fittest, and while some scientists maintain that this principle is all-sufficient, the

majority who hold to it believe that though we can explain by it many phenomena of instinctive behavior, yet our knowledge of the subject is so very imperfect that it certainly leaves much unexplained; there may very well be, then, some other principle which acts in conjunction with natural selection.

The various forms of animal behavior which we have noted thus far have several points in common; they are all inherited; all are performed without previous experience and in the same way by similar individuals; they have not been learned; they are involuntary. But for most animals such simple methods of organic response are insufficient to meet the varying conditions of their environment. Instinctive acts, the highest form of inherited automatic activity, are early modified by experience. The experiment was made of placing before a very young chick some finely cut bits of bright yellow orange rind; the chick pecked at them as it did instinctively at any attractive object, but found them distasteful and let them alone. Then a part of a finely chopped, hard-boiled egg was placed before the chick; it ate the white of the egg but left the yolk untouched, its yellow color recalling the experience of the orange rind, and the young bird could not distinguish between them by sight or smell. Thus it had learned to profit by experience and so manifested the presence of an effective consciousness in a distinctly volitional act, — a manifestation of intelligence. Here the association of the disagreeable taste with the yellow color was sufficiently vivid to prevent the chick from pecking at a similar object.

The intimate association of intelligence with instinctive acts may be brought about by the necessity for a choice between several instincts which may be presented to the animal's consciousness at one and the same time. The cat sunning herself at the bottom of the house steps is suddenly confronted by a small terrier. She may follow her instinct to run and seek shelter in the house; she may stand her ground and follow her instinct to scratch; or she may climb the neighboring fence or tree. Thus several instincts, any one of which may be effective, present themselves at the sight of the young dog, and the necessity for choosing between them makes her action, which would otherwise be purely instinctive, an intelligent one; but

we can hardly suppose that she stops to reason as to which of the three means of escape is likely to prove the most efficient.

We must regard intelligent behavior, then, as a form of activity growing out of individual experience rather than as directly inherited. It may, however, become automatic. When the necessity or desirability of the same act is constantly recurring in the life of the individual under the same conditions, it is performed repeatedly in the same manner, the manner which experience has shown to be effective or satisfactory; and in time it becomes a habit, a mode of procedure as automatic as the instinctive act, but differing from it in that it is an acquisition of individual experience, which according to most biologists has not been inherited and cannot be transmitted.

Intelligence manifests itself in animal life in the most varied ways, for it is only through intelligence that the individual is capable of adapting itself to the variable conditions of its environment. Instead of the stereotyped methods of procedure manifested in instinctive acts, we find different members of the same species meeting these conditions in different ways and thus exhibiting a distinct individuality; even the same individual will not necessarily meet the same conditions invariably in the same way, and often in a complex situation the successful performance of the act may be attained only after repeated experiments, the correct solution being accidentally hit upon. But because the animal thus exhibits intelligence, we must guard against attributing to it the ability to reason. It is extremely probable that a careful study of many forms of intelligent behavior which seem to be the result of reasoning are simply manifestations of intelligence.

This distinction between simple intelligence and reason is a very convenient and at the same time a very real one. Simple intelligence prompts the animal to repeated experiments of various means to meet a new condition, until by chance it attains the successful method, and this result being obtained the animal is entirely satisfied. Man on the other hand, confronted by a condition requiring a new method of procedure, is capable of considering the matter first in all its aspects, noting the various possible solutions, weighing the factors which in each are likely to lead to success or failure, until by a process of

estimating the relation of cause and effect he arrives at the proper method of meeting the new situation. Or, if reason alone does not furnish a solution or appears impracticable, he may pursue much the same method of experiment as any other intelligent animal; but, the result once obtained, he proceeds to consider the causes which have brought it about, he resorts to abstraction and generalization, and thus exhibits not only intelligence but a power of reasoning. Whether any animal except man possesses this faculty has often been asked, and our exact knowledge of animal behavior is so slight as to make it difficult to reply. Experimental evidence is chiefly against the theory that animals can reason in the strict sense of the word, while simple intelligence appears to be amply sufficient to meet all the usual though varied demands of their existence under changing environments. The popular stories of reasoning in animals are numerous, but on scientific examination most of them will be found to be explicable on the simpler hypothesis.

The manifestations of intelligence in animals are very numerous, and some have been studied with great care. Among the lower animals they are most conspicuous in the insects. Examples are furnished by the military ants of the tropics, which form veritable armies and wage war on neighboring colonies; by the harvesting ants of Texas as they meet the varied conditions incident to clearing the ground about their nests for the growth of the ant rice, which they harvest six months later; by the methods employed by some of the wasps in burying their prey, — they dig a hole in the ground and try to put the spider which they have killed into it; if the spider is too large the hole is enlarged; after burying it the wasp grasps a stone in her jaws and with it pounds down the earth over the hole. It is impossible here to enter into the details of these various activities, but they all illustrate a remarkable interplay of instinct and intelligence, the intelligence being manifested along the line of the adaptability to new or untried conditions and consisting chiefly in the ability to profit by chance successes.

As a further illustration of this last point let us take an instance from the behavior of the higher animals. Many dogs readily teach themselves to open a door or gate by pressing the latch. The casual observer remarks on the marvelous reasoning

power of the animal, which enables him to go directly to the latch and press it in precisely the right manner each time. In those cases, however, where the dog's behavior has been observed from the very beginning, it is found that reason is not at the bottom of the act, but simple intelligence, which has utilized the results of many experiments. Thus the first time the dog approached the closed door and sought to open it, he followed his instinct by scratching and pushing against it; eventually his paws came upon the latch and the door swung open. After repeated experiences he came to associate scratching in a particular place with the opening of the door, and finally the pressing of the latch itself was distinguished as the necessary operation. Thus his experiences became more and more condensed, the many useless, unnecessary movements were eliminated, and the result was what has been called functional selection, the survival of only such movements as were necessary for the successful accomplishment of the act. A young child would attack the problem in the same manner as the dog; an older individual would resort to reason.

There is, then, in animals an innate capacity for meeting the difficulties of new conditions, an ability to accommodate themselves to a changing environment through intelligent experimentation; and this innate capacity, characterized by extreme plasticity, may be conceived to be inherited, although the particular motor manifestations of it in each case are acquired. Just how intelligence is able to modify behavior, it is difficult to say. The impression made on the nerve centers by the performance of an act recurs at its repetition, but this memory is selective; it omits details, retaining only the salient features of the act, thus giving psychologically a generic image; it is a concentration of experience.

There are one or two forms of animal behavior, which we have not yet touched upon, which deserve a word of notice here. One of the most familiar manifestations of activity in animals is play, observable in animals of almost any age to some extent, but more especially in the young. The puppy seizes a shoe, shakes it violently, and tears it to pieces; he tussles with another puppy, biting his ears and legs as they roll over and over. The kitten rolls a ball across the floor, springing

into the air as she follows it; or, crouching stealthily, she advances first one foot and then the other, with eyes fixed on her mother's gently swaying tail, finally pouncing upon it only to receive a box on the ear from her parent. The calf or the colt kicks up his heels and gambols about the pasture. Such kinds of behavior we recognize as play; they are of no immediate advantage to the individual; the animal appears to indulge in them merely for the pleasure derived from such a form of activity; they do not seem in any way necessary to the satisfactory performance of the various functions of animal life.

Psychologically it is doubtless the pleasure derived from play which prompts the animal to indulge in it. When, however, we seek for the underlying biological end which play is to accomplish in the economy of the individual or of the race, we find two theories in the field. According to one the animal plays when stimulated by a superabundance of health and strength; he works off his surplus energy, as we say in popular language. But while the instinct to play may be called into action by a condition of physical well-being, it is scarcely probable that the biological end is to reduce a superfluous amount of energy. If animals played only when in a condition of exuberant health and strength, we might be led to this conclusion, but this seems far from being the case. Any one who has observed a couple of dogs at play will have seen them start up again and again after they have lain down from sheer exhaustion; the moment they have recovered breath, as it were, they are at it again. Superfluous energy must long have been used up; they must rest until they have regained sufficient for the next attack. Animals will even play to some extent when they are ill, at a time when physical energy is below the normal. Taking such facts into consideration, the first theory of play does not appear entirely satisfactory.

The second theory considers that the biological end of play is the training of the individual for the future requirements of life. Hence play is most manifest in the young animal; the kitten springing at her mother's tail is training her muscles and nerves for their later use in the process of catching birds and mice; there is necessary the same coördination of movements and the same concentration of attention, and the skill attained at this time of life will save her from losing many a desirable meal later

on. The puppy, tussling with his fellow, pulling him about and biting him, is preparing for real fighting with other dogs when he grows up. Thus play is a part of the schooling of the animal for meeting the more strenuous requirements of adult existence, a schooling which is never necessarily completed, hence the play instinct may even crop out in later life. It is then a potent factor in natural selection, for those individuals which have this instinct most highly developed, are most likely to survive in the struggle for existence under natural conditions; under domestication the struggle loses much of its intensity just as in civilized man, where it is largely replaced by rational choice. But among wild animals we can readily see that the absence or subnormal development of the play instinct would militate against the survival and propagation of the individual.

The social behavior of animals merits likewise a brief notice. It is a matter of common observation that many kinds of animals live in groups or herds or colonies, the various members of which take a greater or less interest in their associates. Among the lower animals such communities are most highly differentiated among some of the insects, where, as in the case of the bees, wasps, and ants, there is often a marked development of a division of labor. Many fishes move in schools; many amphibians and many reptiles congregate together; birds usually move in flocks; herds of mammals are the rule. In such associations the general welfare becomes to some extent of common interest; in herds of buffaloes the old males will collect in front of the females and the young and receive the attack of the enemy. In troops of monkeys a cry of alarm or of pain will bring companions from all sides. The fundamental factor in social behavior must undoubtedly lie in the phenomena of reproduction and the consequent preservation of the best interests of the race. It is this which prompts the stronger individuals to protect the weaker and the young, rather than any impulse of magnanimous self-sacrifice. The most highly differentiated feature of social organization, the monogamous family, is found in a very few animals below man, and such families appear to be merely the result of simple intelligence resulting from the necessity for nest-building and caring for the young during and after development. There is no satis-

factory evidence that such associations among animals are the result of the formation of a rational ideal of the family, as is the case in the human race, where the monogamous family of the more highly civilized countries must be regarded as a realized ideal, which has been attained out of such communistic associations as exist still among some savage tribes.

In the evolution or development of social behavior, imitation, conscious or unconscious, undoubtedly plays a part. Unconscious or instinctive imitation is exemplified in some young birds, which require to be taught to peck before they will perform the act. The monkeys furnish many examples of conscious or intelligent imitation; one observed a man prying off the lid of a box, and when given a similar box imitated him precisely and removed the lid. A careful study of instances of imitation in animals leads us, however, to the conclusion that reason plays no part in the process except in man; it is either instinctive or simply intelligent.

The emotions of which we see evidence in animals are numerous, especially in the higher vertebrates. Love, hate, anger, fear, joy, grief, pride, shame, and even moral and æsthetic emotions, have all been attributed to animals, and the majority of them are certainly often manifested. But it is sometimes difficult to discriminate between certain varieties of emotions. Thus, when your terrier leaps from your best sofa pillow as you suddenly open the door, his hangdog expression is quite as likely to be due to fear of reprimand or punishment as to shame, to which you are more inclined, perhaps, to attribute it. There are many stories of the manifestation of revenge by elephants, some of which are certainly authentic. Sympathy is an emotion often manifested by monkeys; they have been observed to fold a wounded companion in their arms in a very human fashion and to cuddle up beside one which was ill, as a child might do. But as to the subtler emotions, such as the moral and the æsthetic, it is extremely doubtful if they exist at all in animals below man; their existence demands the presence of an ideal which implies the exercise of reason, and there is no direct evidence that such an ideal ever enters into the consciousness of any animal. As we observed at the beginning of this chapter, we are very prone to attribute to other animals the same

emotions which we ourselves feel, overlooking the simpler and more logical explanation of the facts observed. The cat refrains from jumping upon the table and helping herself out of the cream pitcher, not because she knows it is wrong so to do, but because she has had her ears boxed for doing that or some similar act before, and the memory of it has not faded away.

Our conclusion, then, in so far as our present knowledge of the facts leads us, must be that in most animals instinct plays a very large rôle in meeting the ordinary problems of life, a much larger rôle than in man; that in the majority of animals intelligence takes advantage of past experience, and instincts become modified to meet the requirements of a varying environment; and that such intelligence seems to be sufficient for the performance of the activities of animal life without the aid of rational thought, which thus appears to be confined to man. this power of reasoning we can, however, conceive to have been evolved through natural selection from the higher manifestations of intelligence, through an attempt to explain the phenomena of life by abstraction and generalization, and the consequent formation of an ideal. Such, epitomized, is our conception of the problem of animal behavior to-day. It offers one of the most fascinating and promising subjects for investigation in the whole range of the biological sciences; especially in the careful observation of the activities of young animals and more particularly of the higher vertebrates may we hope for some of the most valuable contributions to our knowledge of animal behavior.

# CHAPTER XIV

## THE HISTORY OF ZOÖLOGY

There was little exact knowledge in any branch of natural history before the beginning of the eighteenth century, and it did not really rank as a science before the nineteenth; the majority of the earlier writers on biological subjects were philosophers, whose speculations have in some cases turned out to be correct, but as a rule flew wide of the mark, as theories not founded on facts are apt to do. When we consider the vast amount of superstition and fable prevalent in every century of the past, we may well be surprised that so much of truth concerning the organic world was discovered and recorded; even to-day the advance of our knowledge in the field of biology is slow, and the search after truth laborious, while the extent of general misconception concerning even the simpler processes of life, which should be matters of common information, is painfully great. On the other hand, never have the various branches of natural history been studied with such zeal and self-sacrificing devotion as at present; and in their application to the directly practical sciences of medicine, hygiene, sanitation, and agriculture are doing more than ever before for the betterment of the human race.

The Greek philosopher, Aristotle (384–322 B.C.), has been called the father of natural history, for his writings are the earliest known to us that have any scientific interest. We have portions of three of his works on zoölogy, entitled "The History of Animals," "The Parts of Animals," and "The Generation of Animals." He considered animals in their broadest aspects, systematically, structurally, physiologically, embryologically, and in their relations to their surroundings. He was well fitted for his work; descended from a line of physicians, living near the sea with its infinite variety of life, with leisure and wealth and a li-

brary of such works as had then been written on the subject, and, above all, a deep philosophical and scientific spirit, all combined to produce results not surpassed for many centuries. We are constantly surprised at the accuracy of many of his statements, some of which have been verified only within recent years; on the other hand, we need not wonder at the many inaccuracies in his writings, remembering how much credence was then given to tradition, and how laborious must have been the acquisition of facts. We know that his method was correct, for we find him saying in his "History of Animals": "We must not accept a general principle from logic only, but must prove its application to each fact; for it is in facts that we must seek general principles, and these must always accord with facts. Experience furnishes the particular facts from which induction is the pathway to general laws." He distinguished some five hundred species of vertebrates, and speaks of a great variety of invertebrates. He recognized two great groups of animals, those with blood (*ἔναιμα*) corresponding to our vertebrates, and those without blood (*ἄναιμα*) consisting of our invertebrates, for he did not recognize that blood may be colorless. Each of these groups he divided into four, so that his system of classification was as follows: —

Animals with blood (*ἔναιμα*):

1. Viviparous animals (*ζωοτοκοῦντα ἐν αὐτοῖς*).
2. Birds (*ὄρνιθες*).
3. Oviparous quadrupeds (*τετράποδα ἢ ἄποδα ᾠοτοκοῦντα*), including our Reptilia and Amphibia.
4. Fishes (*ἰχθύες*).

Animals without blood (*ἄναιμα*):

5. Soft animals (*μαλάκια*), such as Cephalopoda.
6. Soft animals with shells (*μαλακόστρακα*), such as Crustacea.
7. Insects (*ἔντομα*).
8. Animals with shells (*ὀστρακοδέρματα*), such as Echinodermata and many Mollusca.

He also speaks of other animals, such as jellyfishes and sponges; that he considered the latter as animals is a matter of some surprise, but, on the other hand, his placing the hydroids with plants is a very natural error. Although he advocated the

study of facts, he not infrequently followed the theories or assertions of others without verifying them; he believed in the theory of spontaneous generation, or abiogenesis, as it is sometimes called, not only for small animals, but for such as eels, frogs, and snakes as well, and his knowledge of anatomy as well as of physiology was very incomplete. He was not the first to believe in a possible evolution of higher animals from lower; this theory was held by other Greek philosophers both before and after him. That he was fundamentally a lover of nature is very apparent in his writings, and it is interesting to find him urging the study of the lower animals, as when he says: "Hence we ought not with puerile fastidiousness to neglect the contemplation of more ignoble animals; for in all animals there is something to admire, because in all there are the natural and the beautiful."

No other writer of any note on natural history appears in the classical period until Pliny the elder (23–79 A.D.), the Roman general. His lengthy work on this subject was, however, a compilation of stories and reports from many sources, and as he inserted indiscriminately the fabulous and the true, his writings are of no scientific value. He further took a very retrograde step in substituting for the natural classification of Aristotle one based on habitat, so that he recognized land animals (terrestria), aquatic animals (aquatica), and flying animals (volatilia).

In the next century Galenus (130–200), a celebrated Greek physician and anatomist, who lived for some time at Rome, contributed somewhat to the knowledge of mammalian anatomy, but he is the last of the real scientists until the sixteenth century. Throughout the middle ages scientific investigation in natural history was unknown; the book on zoölogy at that period dealt with such animals as the phœnix, the dragon, and the unicorn. Many religious teachers, however, wrote exclusively on the philosophical side of the subject, the general tendency, culminating in the works of Augustine (353–430), being an inclination to the theory of the Greeks of spontaneous generation, and a belief in a gradual development of life from the lower to the higher, — in short, a suggestion of evolution in place of the literal interpretation of the Mosaic account of creation. Augustine being a teacher of acknowledged authority, his beliefs had numerous followers throughout the middle

ages, one of the most notable being Thomas Aquinas (1225–1274). Several books on natural history appeared during the middle ages, most of them being based on Aristotle and Pliny. One of the most voluminous was by the Dominican, Albertus Magnus, in the thirteenth century (1193 or 1205–1280).

With the renaissance of the sciences in the sixteenth century, several writers of note appear, and the study of animals received a new impetus. The knowledge of anatomy was considerably advanced through the study of the structure of the human body, which was zealously carried on at Padua under Vesalius (1514–1564) and his pupils. Two notable works on zoölogy were published in this century; one was by the Englishman, Wotton (1492–1555), who followed Aristotle pretty closely, his voluminous work "On the Distinguishing Characters of Animals" ("De Differentiis Animalium"), published in 1552, elaborated the system of Aristotle, to which he added the group of flower animals or zoöphytes; this work was a precursor of the books on the classification of animals, which appeared in the next two centuries. The other zoölogy was by the Swiss naturalist, Gesner (1516–1565), whose huge "Historia Animalium," of some 4500 folio pages, appeared about the same time as Wotton's book. It is rather encyclopedic, containing a complete bibliography of zoology and descriptions of numerous animals with no arrangement except into a few large groups, which were essentially those of Aristotle; he still retains such interesting animals as sea serpents, hydras, and dragons, of which illustrations are furnished.

The seventeenth century is noteworthy for important discoveries in many fields of science, and this is eminently true of the biological. The first, and in many ways the most important ever made, was the discovery of the circulation of the blood by Harvey in 1619, the results of which he published in 1628 in a pamphlet entitled "Exercitatis anatomica de motu cordis et sanguinis"; this was the real beginning of physiology and of the correct interpretation of anatomy. Harvey also did some valuable embryological work later in the century, studying especially the development of the chick. In 1645, the Italian, Severino (1580–1656), published his "Zootomia democritea," which contained many anatomical drawings, intended especially

for the student of medicine. The chief zoological advances of the century were due to the improvement of the compound microscope, which had been invented in the last decade of the sixteenth century by the Dutchmen, Hans and Zacharias Janssen. By means of this, the Italian scientist, Malpighi of Bologna (1628–1694), made many discoveries in the minute structure of the organs of the higher animals, some of which still bear his name, and was the first to contribute to the knowledge of insect anatomy in his "Dissertatio de bombyce," published in 1669. The Dutchman, Schwammerdam (1637–1680) of Leyden, in his work, "The Bible of Nature," described with remarkable accuracy the structure of many insects and mollusks. Leeuwenhoek of Delft (1632–1723) made extensive use of the microscope and thus discovered many histological structures, such as blood corpuscles and the striations of muscle fibers, as well as many minute animals, notably numerous Protozoa and Rotifera.

One of the most interesting microscopic discoveries of the century was made at Leyden by the student von Hammen or Hamm, in 1677, when he found for the first time the spermatozoa of animals, whose real significance was not recognized for some time; they were then called the sperm animalcules. Previously the ovum had been considered the real essential to reproduction, the spermatic fluid being regarded as furnishing merely the requisite stimulus for its development. There were further two theories as to the method of development: according to one, the theory of epigenesis held by Harvey, the embryo arose from the ovum by its gradual differentiation into the organs of the adult, a theory which we know to-day to be correct; according to the other, called then the evolution or preformation theory (not evolution as we use the term technically to-day), which was held by Malpighi, the adult existed in miniature completely formed in the ovum and needed merely to increase in size to reach maturity. The discovery of the spermatozoa gave rise to two factions, the ovulists or ovists, and the spermatists or animalculists. The former held as previously that the embryo arose from the ovum alone; the latter maintained that the head of the spermatozoon contained a miniature model of the adult, — they drew figures of it, — which increased in size

by the nutriment stored in the ovum. The theory of preformation led at once to a rather incomprehensible conclusion, for each ovum or spermatozoon must not only contain the adult in miniature, but within this the model of the next generation, and that of the succeeding, and so on *ad infinitum*.

During all this time the theory of abiogenesis, or the spontaneous generation of living things from lifeless or inorganic matter, was pretty generally believed; it was the Italian, Redi (1626–1698), who first gave a foundation of fact for the opposite theory of biogenesis, that living matter arises only from living matter. He showed by experiment that the maggots found in decaying meat were developed from the eggs which flies had deposited there, and hence did not arise spontaneously as was previously supposed. The theory of spontaneous generation did not die, however, until well along in the nineteenth century. It was in the latter half of the seventeenth century that the word "cell" was first used; two English botanists, Hooke and Grew, applied it to little cavities they found in vegetable tissue, and Malpighi described structures which we should call "cells."

The last great work of the seventeenth century was the "Synopsis Methodica Animalium" of the Englishman, Ray, published in 1693. It was an attempt at the classification of animals on the basis of structure, and, though a great advance in this respect, it was unfortunate in following closely the classification of Aristotle. Ray, however, was the first to grasp the conception of species, and thus advanced one step nearer to the goal, which was finally reached by Linnæus in the next century.

Finally, we should note in this century the natural philosophers. The Englishman, Bacon (1561–1626), recognized the variation in organisms, and appears to have entertained a general conception of organic evolution. Descartes (1596–1650), the French philosopher, believed all things to have developed according to natural laws, rather than by sudden acts of special creation, the prevalent theory of that day. But the German, Leibnitz (1646–1716), was the most outspoken in his belief concerning the fundamental relationship between animals. He says: "All natural orders of beings present but a single chain, in which the different classes of animals, like so many rings,

are so closely united that it is not possible, either by observation or imagination, to determine where one ends or begins."

Thus the seventeenth century paved the way for the great advance made in natural science in the succeeding hundred years; it was marked by several important discoveries, and by the great improvement of the microscope; but after all the greatest service which it rendered to science was the inauguration of the spirit of independent investigation and research into the facts of nature, accompanied by an increasing disinclination to accept mere assertions as facts. On the other hand, we must remember that on the philosophical side, animals were held to be the result of special creation and immutable; the boldest thinkers could venture merely to point out that variations did occur, to suggest the mutual relationships of animals, and hesitatingly to offer the theory that there might be laws of nature sufficient to account for all natural phenomena without introducing any supernatural agency.

The eighteenth century is marked by great advances in knowledge along morphological lines. In nearly all the countries of Europe there were naturalists making dissections of animals and drawing them; their work was carefully done, and their results of the greatest value, but we have not space to review them here, and a mere enumeration of the names of these scientists would be of little value. In the field of embryology, however, we should note the German, Wolff, who in 1759 gave the most accurate description of the development of the chick that had appeared up to that time; he showed that the growth of the embryo was due to an upbuilding of the various organs, an epigenesis, and that there was no preformation, as was believed by the majority of the scientists of that day. Unfortunately his work and conclusions did not receive the recognition they deserved until much later, for he was violently opposed by another German, von Haller, an eminent physiologist, who firmly upheld the older theory of development. Much was learned about the geographical distribution of animals during this century, through such extended voyages as those of Cook and Bougainville. In this way, too, Europeans became familiar with many new animals and valuable collections were started.

There is little doubt that the rapid accumulation of zoological knowledge would have led to dire confusion in the subject if Linnæus (1707–1778), the Swedish naturalist, had not devised a rational system of classifying animals. His great work, the "Systema Naturæ," first appeared as a small pamphlet, in 1735; it passed through thirteen editions, the last appearing in ten volumes after the author's death; the twelfth edition was in three volumes, and was published in 1766–1768. The tenth edition, which appeared in 1758, is taken as the starting point for our modern system of classification. He divided the animal kingdom into six classes, these into orders, the orders into genera, and the genera into species, and devised the binomial nomenclature as we have already noted in Chapter II, each animal being designated by two names, the generic name followed by the specific name. His six classes consisted of the Mammalia, Aves, Amphibia (including our present Reptilia and Amphibia), Pisces, Insecta (including our entire Arthropoda), and Vermes (comprising all the remaining invertebrates). He instituted further brief diagnoses of species, so that a new species could be readily placed in its proper position in the system. He did not, however, recognize the fundamental distinction between vertebrates and invertebrates, and in this respect fell behind the older systematists, Aristotle, Wotton, and Ray. His classification was further highly artificial in many ways, since he relied too much on the characteristics of a few organs instead of the entire structure of an animal. But the system was correct, and so forms the basis of systematic zoölogy to-day.

There could not be a greater contrast to the dry, systematic work of Linnæus than the entertaining and speculative writings of the French naturalist, Buffon (1707–1788). His great work, the "Histoire Naturelle," in many volumes, contains interesting accounts of animals, their habits, and relations to their environments, but with no attempt at classification. In the earlier editions of this book he held to the current views of special creation with the immutability of species; thus he says, "We find him, the Creator, dictating his simple but beautiful laws and impressing on each species its immutable characters." Later, however, he began to recognize a more intimate relationship

between animals; thus he considers the ape a degenerate man, and points out that by reasoning we should infer that they had a common ancestor, which in one case gave rise to a being of a higher order, the man, and in the other degenerated into a lower type of organism, the ape. In the same way the ass is a degenerate horse and the two had a similar origin. He hastens to add, however: "But no; it is certain by revelation, that all animals have shared the benefits of creation; that the first pair of each and every species has issued completely formed from the hands of the Creator; and we are forced to believe that they were much the same as their descendants are to-day." It thus appears that the facts of zoology led Buffon to a conviction of the evolution of animals, while, on the other hand, he felt bound by tradition to insist on special creation. Whether he was serious in this latter point has been much discussed by later writers. In other passages in his writings he shows clearly that he recognized the principle of the struggle for existence and the elimination of the unfit, but without apparently seeing the relation between these factors and the evolution of animals.

The naturalist who contributed the most to the theory of evolution in the eighteenth century was Erasmus Darwin (1731–1802), grandfather of the celebrated author of the "Origin of Species." He was a physician, a poet of considerable ability, and a profound student of nature. His large work, the "Zoonomia," a medico-philosophical treatise, was published in 1794. He became a firm and outspoken believer in evolution, and in this book brings forward a most logical series of arguments in favor of it; and lest he should appear irreverent in preferring this to the view of special creation he says, "For if we may compare infinities, it would seem to require a greater infinity or power to cause the causes of effects, than to cause the effects themselves; that is, to establish the laws of Creation rather than to directly create." He recognized the variation of organisms, but instead of seeing the cause of these variations in environment, as Buffon did, he believed it to be inherent in the organism itself, thus anticipating Lamarck's theory. He was fully aware, however, that his theory was incomplete, and believed that the real cause of evolution was practically inconceivable.

It is interesting to note that this same difficulty was felt at about the same time by the great German philosopher, Kant (1724–1804). His views, so clearly stated in 1790, represent the most advanced thought of the century on the subject of evolution. He says: "The agreement of so many kinds of animals in a certain common plan of structure, which seems to be visible not only in their skeletons, but also in the arrangement of the other parts, so that a wonderfully simple typical form, by the shortening and lengthening of some parts and by the suppression and development of others, might be able to produce an immense variety of species, gives us a ray of hope, though feeble, that here perhaps some results may be obtained, by the application of the principle of the *mechanism of Nature*, without which, in fact, no science can exist. This analogy of forms (in so far as they seem to have been produced in accordance with a common prototype, notwithstanding their great variety) strengthens the supposition that they have an actual blood relationship due to derivation from a common parent; a supposition which is arrived at by observations of the gradual approximation of one class of animals to another, beginning with the one in which the principle of purposiveness seems to be most conspicuous, namely man, and extending down to the polyps, and from these even down to mosses and lichens, and arriving finally at raw matter, the lowest stage of nature observable by us. From this raw matter and its forces, the whole apparatus of Nature seems to have been derived according to mechanical laws (such as those which resulted in the production of crystals); yet this apparatus, as seen in organic beings, is so incomprehensible to us, that we feel ourselves compelled to conceive for it a different principle." And elsewhere he writes: "It is quite certain that we cannot become sufficiently acquainted with organized creatures and their hidden potentialities by aid of purely mechanical natural principles, much less can we explain them; and this is so certain, that we may boldly assert that it is absurd for man even to conceive such an idea, or to hope that a Newton may one day arise to make even the production of a blade of grass comprehensible, according to natural laws ordained by no intention; such an insight we must absolutely deny to man."

There were many speculative writers in the eighteenth century who theorized about evolution, but in most instances their conjectures were so wild and their surmises had so broad a foundation in medieval fable and classical mythology that their works did nothing for the advance of the science; they are interesting from the historical point of view, but need not detain us here.

Passing from the eighteenth to the nineteenth century, one of the first and most important zoologists we meet is Lamarck (1744–1829), whom we have already noticed in the chapter on theoretical biology. There has been much diversity of opinion as to his ability, but to-day he is very generally recognized to have been a man of real genius. He was interested at first in botany, became intimately acquainted with Buffon, and in 1766 wrote an article in which he expressed his disbelief in the theory of spontaneous generation and his belief in the immutability of species. This article was not published until 1794; whether he still entertained the same belief at that time is a matter of doubt; at any rate he took up the study of zoology at that period, and his views soon changed. In 1802 he introduced the term *Biology*, and it is interesting to note that the German naturalist, Treviranus (1776–1837), suggested the word in the same year. Lamarck's work on animals led to his making several improvements in the system of classification. He introduced the terms *Vertebrata* and *Invertebrata* and organized the groups Arachnida, Crustacea, and Annelida. He further recognized that all animals cannot be arranged in a linear series from the lowest to the highest, but rather in a system of treelike branching; this was the first attempt at such an arrangement, which has since been greatly elaborated. His most important written work was the "Philosophie Zoologique," which appeared in 1809. In this he unfolded his theory of evolution, which of course necessitated the mutability of species; this, he concluded, was brought about by the action of the environment on the organism; the necessity for a part gave rise to it; it was then developed through use and inherited by succeeding generations. This theory he held practically unaltered until the time of his death; its similarity to the theory of Erasmus Darwin has been repeatedly pointed out, but there

seems to be little ground for believing that Lamarck knew of Darwin's work.

The German poet, Goethe (1740–1832), though living at the same time as Lamarck, does not appear to have known of the "Philosophie Zoölogique." He was a keen naturalist and a firm believer in evolution. He introduced the term *Morphology*, and suggested various theories, some of which have proved correct and others not.

One of the greatest comparative anatomists of the nineteenth century was Cuvier (1769–1832), who was also the first to establish palæontology on a scientific basis. He was born in Germany, but when about twenty-five removed to Paris. His chief works were "Le règne animal distribué d'après son organization" and "Leçons d'anatomie comparée." His knowledge of animal structure far exceeded that of his contemporaries, and he viewed the facts of comparative anatomy from a much broader standpoint than any naturalist had done up to that time. In this way he was able to take in the totality of structure and thus saw the broader relationships of animals which had escaped his predecessors. Hence, instead of taking the six classes of Linnæus as the primary divisions of the animal kingdom, he distinguished four large groups which he called branches; these correspond to our types, the name *type* being first introduced by the French writer, de Blainville (1777–1850). The four branches of Cuvier were: —

Branch
I. Vertebrata.
II. Mollusca (including also the Tunicata, Brachiopoda and Cirripedia).
III. Articulata (comprising the Arthropoda and the Annelida).
IV. Radiata (consisting of the round and the flat worms, the Echinodermata, the Cœlenterata, and the Protozoa).

This was by far the greatest advance that had been made in the classification of animals since the days of Linnæus; but he considered each branch as complete in itself and independent of the others. He became the opponent of evolution, holding to the immutability not only of species but of varieties, and most pitilessly opposed Lamarck in all his doctrines. His wide reputation as an anatomist and palæontologist gave him an enormous influence and great prestige, and it was without doubt due

directly to him that the principle of evolution made no notable advance between Lamarck's "Philosophie Zoologique" and the "Origin of Species" of Darwin.

Very interesting in connection with the study of Cuvier is the work of his contemporary in Paris, the elder St. Hilaire (1772–1844), who, though a distinguished naturalist, was even a greater philosopher. He was not so radical in his views on evolution as Lamarck, although he recognized in the environment the cause of variation. His "Philosophie anatomique" was published in 1818. A most interesting and important encounter occurred in 1830 at the Academy of Sciences in Paris between St. Hilaire and Cuvier. In the discussion St. Hilaire upheld the unity of structural plan in all animals; while Cuvier pointed out the different plans of structure in the various types. The former's principle, though correct, was based on facts which were wrong, while the latter cited facts which were correct to support a wrong principle. It is not surprising, then, that Cuvier withdrew from the discussion with the greater glory, and this was another factor in holding back the evolutionary idea in the remainder of the first half of the century.

As a palaeontologist Cuvier refused to recognize any relationship between the animals of the different geological periods; he held that each period was brought to an end by a cataclysm or revolution of nature, and that the fauna of the succeeding period arose by a new creation. Hence it was a matter of great biological importance when the distinguished English geologist, Lyell (1797–1875), published his "Principles of Geology" in 1830–1833, in which he brought out the lines of evidence for the continuity of action of natural forces in the history of the earth without any violent interruptions.

Not long after this the cellular structure of plants and animals was noted, and the term *protoplasm* came into use. We have seen that the word "cell" was used much earlier, but it was not until 1838 that the German botanist, Schleiden (1804–1881), advanced the theory that all plants consist of little chambers or cells; he regarded the cell wall as the important part. In the following year, 1839, the same theory was advanced for animals by the German, Schwann (1810–1882). The word "protoplasm" was first used by Purkinje in 1840 for the substance of which

young embryos are composed. In 1840 it was first applied to the contents of the cell by von Mohl. Later it was discovered that there were cells without walls and that the protoplasm was the real essential. The cell theory formed the foundation of the science of histology and revolutionized the conceptions of pathology.

Ever since the spermatozoa had been discovered in 1677, there had been much speculation as to their nature and function. Many held, as we have already noted, that they contained a miniature model of the adult; others believed them to be merely parasitic animals in the seminal fluid. It was nearly the middle of the nineteenth century before the union of ovum and spermatozoön was observed, and a few years later the development of the spermatozoa from the cells of the testis was ascertained; thus the part they play in fertilization was at length determined, and the dispute between ovists and animalculists settled.

The number of naturalists who made valuable and extensive contributions to knowledge in zoology during the first half of the century was very great, but in a brief review of the history of the subject we must pass them over; it will suffice to note a few names, while many others are of almost equal importance. Thus the Russian, von Baer (1792–1876), discovered in 1827 the mammalian ovum, and in his work on the chick confirmed Wolff's account of the development of the organs from layers of cells, the germ layers. The English scientist, Owen (1803–1893), made very extensive studies of vertebrate anatomy, and wrote a text-book on the subject. The French zoölogist, the elder Milne-Edwards (1800–1885), made valuable contributions to anatomy and physiology in his "Leçons de l'Anatomie et de la Physiologie comparée." One of the most interesting figures of the middle of the century was the celebrated Swiss naturalist, Louis Agassiz (1807–1873), who came to America, and as a professor at Harvard University founded the large school of naturalists in the United States. He was the last of the great scientists to hold to the fixity of species, and expressed his belief in an essay, published by a curious coincidence in 1859, the year in which Darwin's "Origin of Species" appeared. The wide influence of Cuvier in opposing the theory of evolution lends an

added interest to the writings of Herbert Spencer (1820–1903), who was one of the few outspoken evolutionists of that period.

Thus by the middle of the century a vast amount of accurate knowledge in zoology had been accumulated; theories had been proposed to account for the resemblances and differences of animals; and while some naturalists and philosophers held to the theory of evolution, the general belief was in the theory of special creation; in fact, a scientist was apt to be considered not quite sound in judgment by his colleagues, if he proclaimed himself an out-and-out evolutionist. It was into such influences as these that Charles Darwin (1809–1882) came. A short course of study at the universities of Edinburgh and Cambridge was followed by the most important event in his early life, the voyage of H.M.S. *Beagle* (1831–1836), on which he sailed as naturalist, circumnavigating the globe. During this time he was still a special creationist, but the broad knowledge of natural history gained from visiting so many new countries clearly raised doubts in his mind as to the correctness of the older theory, and we find him on his return in 1837 undertaking a systematic study of variation; to use his own words: "I worked on true Baconian principles, and without any theory collected facts on a wholesale scale, more especially with respect to domesticated products, by printed inquiries, by conversation with skillful breeders and gardeners, and by extensive reading." The idea of natural selection first occurred to him in the following year, but he did not write out his theory until 1844, and even then did not publish it; for he received no encouragement to do so from scientific friends with whom he discussed his views. He continued the same line of study, and in 1858 received from his friend Wallace (1822– ) a recently completed manuscript, in which theories almost precisely like his own were expressed. Then through the influence of friends Darwin was induced to publish an abstract of his manuscript of 1844, in the same periodical with the manuscript of Wallace. In the following year, 1859, the "Origin of Species" was published, and in the course of the succeeding twenty years converted the entire scientific world to the theory of evolution. In 1858 both Darwin and Wallace believed that natural selection was the only factor in the evolution of species; later in life Darwin came to believe that while it was the prime factor, yet use and disuse were also

efficient agents in the modification of species. Wallace, however, has always adhered to his original theory, and is to-day one of the firmest advocates of the complete sufficiency of natural selection.

To scientists in general, Darwin's theory of natural selection came as something entirely new, but it had actually been suggested by two writers earlier in the century, although neither of them appreciated its full significance. The Englishman, Wells, read a paper before a scientific society in 1813, in which he recognized the principle of natural selection as applying to human races; this paper was published in 1818. Another British writer, Matthew, published a work in 1831, in which he formulated briefly a theory of evolution based on the principle of natural selection. But although Darwin was not the first to discover this principle, his conception of it was original; he was entirely unaware of the works of the earlier writers. Very many writers have dealt with this subject since the publication of the "Origin of Species"; the two whose works have had the widest interest probably are the German, Haeckel (1834–), whose theoretical writings have been criticised chiefly for their inconsistencies, and his fellow-countryman, Weismann (1834–), whose contribution to the theory we have already noted. In England, Huxley (1825–1895) has been one of the most ardent writers on evolution, and has in addition made important contributions to anatomy.

We have already remarked that the first half of the nineteenth century was especially noteworthy for the great advances made in anatomical knowledge; in a similar way the second half was characterized by a truly marvelous increase of embryological knowledge. Much of this was doubtless due to the great perfection brought about in the construction of the compound microscope during this period, and the improved technique employed in preparing objects for microscopic study. Combinations of lenses are now made which give a magnification of 3000 diameters; there are drawbacks to the use of such high powers, however, and for ordinary work it is not necessary to use a magnification greater than about 1000 diameters. By further mechanical devices it is now possible to cut delicate objects into sections a thousandth of a millimeter thick, which thus become

available for study with the very high magnifying powers of the microscope.

One of the most important results of embryological research has been the correction of many errors of classification, for often the real relationship of animals does not appear until their development is known. Thus the studies of the eminent Russian embryologist, Kowalewsky, showed the Tunicata to belong to the Chordata instead of to the Molluscoidea, where they had previously been classified. Many organisms once regarded as distinct species have since been shown to be merely larval stages of other organisms, and finally our knowledge of the minute structure of protoplasm and its various modifications in cells is due largely to improvements in histological technique within the last decade or two of the century.

For the trend of research at the present day, we owe much to the works of Weismann and of Mendel. Weismann's theory of the germ-plasm has proved the greatest stimulus to the study of experimental embryology and the phenomena of fertilization. Mendel's law of the purity of the germ-cells has given the first real foundation for the scientific study of heredity, and it is being elaborated by extensive observations and experiments in breeding. As a direct result of the extended researches in embryology, there has arisen a phenomenal interest in the structure and activities of the cell, and many investigators are devoting their attention exclusively to this line of work; so greatly has our knowledge increased on this subject that it is now recognized as a distinct branch of biology, under the name of *Cytology*. We should note, too, the more precise methods which are being introduced into the study of variation, a subject of much interest through its bearing on theoretical biology; variations are now studied statistically or quantitatively, the extent of variation in some particular characteristic or group of characteristics being measured, and the results tabulated and represented graphically by curves, with mathematical precision.

The second half of the nineteenth century likewise saw great advances in palæontology, the most notable being due to the researches of Marsh and Cope in America. Our knowledge of deep-sea life has been accumulated during this period; many European countries and the United States have sent out expedi-

tions, the most successful perhaps being some of the French and Scandinavian investigations, the voyage of the British vessel, the *Challenger*, 1872–1875, and the three cruises of the *Blake* under the direction of the United States Fish Commission, in 1877–1880, with Alexander Agassiz as naturalist.

To-day biological investigations are being actively carried on in almost every highly civilized country; the centers of this activity are the universities and the zoological and agricultural stations. In almost every university and college are found well-equipped laboratories for zoological research. Most investigators are students or teachers in such institutions; the number of naturalists who devote their time to investigations without teaching is small. Of the various experiment stations the marine are naturally the most extensive contributors to zoological knowledge; of these the most celebrated is the well-equipped station at Naples, founded in 1870 by the German naturalist Dohrn. It is provided with an excellent working library and an unsurpassed aquarium, while its publications are among the finest in the world; scientists of all nationalities repair there for research, and the United States is always well represented. Almost every European country with a seacoast has one or more zoological stations, and many are scattered along the coasts of the United States. Other aids to the study of biology are found in the numerous scientific libraries which have been established within recent years; the valuable collections, such as those of the British Museum in London, the Imperial Museum in Vienna, the American Museum in New York, and the Agassiz Museum in Cambridge; the establishment of aquaria, as at Naples, Berlin, Amsterdam, and New York; and also the maintenance of zoological gardens, such as are scattered over Europe and the United States.

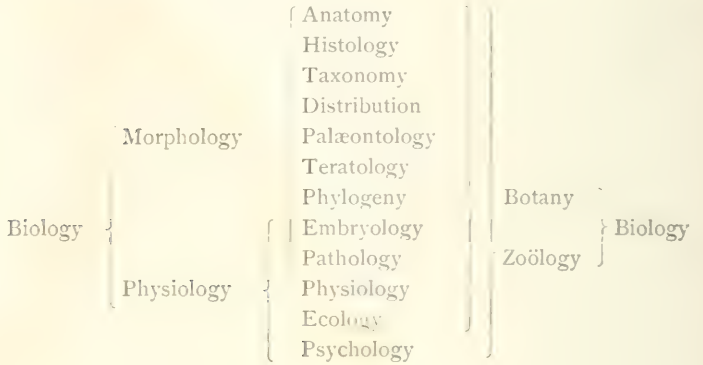
# APPENDIX

## THE RELATION OF ZOÖLOGY TO ALLIED SCIENCES

We have already defined **Zoölogy** and **Botany** as the sciences which deal with the phenomena of animal life and of plant life respectively; hence both are concerned with living matter, with organisms, as distinguished from lifeless matter, such as minerals, and so the term **Biology** (Gr. *βίος*, life, and *λόγος*, discourse), in its broadest significance, the science of life, is often used to include them both. We may, however, speak of the biology of some particular animal or plant, and by this we mean a study of the phenomena presented by the animal or plant during its life history. While **Zoölogy**, then, is that branch of the science of Biology which undertakes to ascertain all that may be known about animals, their structure, their activities, their development, and their relations to other animals, to plants, and to the inorganic world as well, it is customary, however, in most text-books of Zoölogy to treat these matters in a rather general way, and to leave their detailed consideration to more extended treatises, each dealing with some particular phase of animal life. Thus we find that the various subjects included in the study of animals, and of plants as well, may be grouped under the two sciences of **Morphology** (Gr. *μορφή*, form, and *λόγος*, discourse), which has to do with all matters relating to the form or structure of organisms, and **Physiology** (Gr. *φύσις*, nature, and *λόγος*, discourse), which considers the activities or functions of living matter. Inasmuch, however, as structure and function are so intimately associated with one another, these two sciences must be studied to a greater or less extent together. But structure and function are very extensive subjects, so that we have a large number of sciences, each of which deals with

some particular aspect of one or the other or both. Thus **Anatomy** describes the structure merely, and, as the word is generally used, it refers to the macroscopic structure, the general arrangement of parts which can be made out with the naked eye, and hence is sometimes called gross anatomy. **Histology**, or Microscopic Anatomy, on the other hand, describes the minute structure for the study of which the microscope is necessary. **Taxonomy**, or Classification, attempts to arrange plants and animals in natural groups, so as to show as far as possible their relationship to other plants and animals; this science is often called **Systematic Botany** in the classification of plants, and **Systematic Zoölogy** in the classification of animals. The science of the **Distribution** of organisms includes their horizontal or geographical distribution, their vertical or bathymetrical distribution, and their geological distribution, or distribution in time. This latter division of the science deals with animals and plants which have lived in more or less remote periods of the earth's history, and are known to us by their fossil remains; their study constitutes the special science of **Palæontology**, the science of fossil organisms. Occasionally plants and animals develop abnormally; the supernumerary legs and horns which are sometimes found in the higher animals are familiar examples of this phenomenon; such individuals are known technically as monsters, and the science which makes a study of them is called **Teratology**. The science of the development of the individual is known as **Embryology**, or sometimes as **Ontogeny**; it treats of the changes which an organism undergoes from the time when it is in its simplest, most primitive condition up to its adult form; this science is necessarily both morphological and physiological. The science of **Phylogeny** or the development of the different types or races of animals or plants is largely a theoretical science, which by using the facts of Anatomy, Embryology, and Palæontology attempts to trace the evolution of one group of organisms from another. The science of Physiology deals with all the activities or functions of an organism, whether in health or disease, but the phenomena of the latter condition are generally considered under the special science of **Pathology**, a science which is both anatomical and physiological; thus far it has concerned itself chiefly with man,

the domestic animals, and such plants as have a food value. The study of the relations of living organisms to their environment, to other animals and plants, and to the inorganic world constitutes a special science known variously as **Ecology**, **Ethology**, or **Bionomics**. The science of **Psychology**, or of mental phenomena, is properly one of the biological sciences, and we may also mention **Anthropology**, which is the study of the various races of man. The relations of most of these sciences to Morphology, Physiology, and Biology may be shown by the following diagram: —



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